SILVER BOW CREEK INVESTIGATION

Feasibility Study

for the

Warm Springs Ponds Operable Unit

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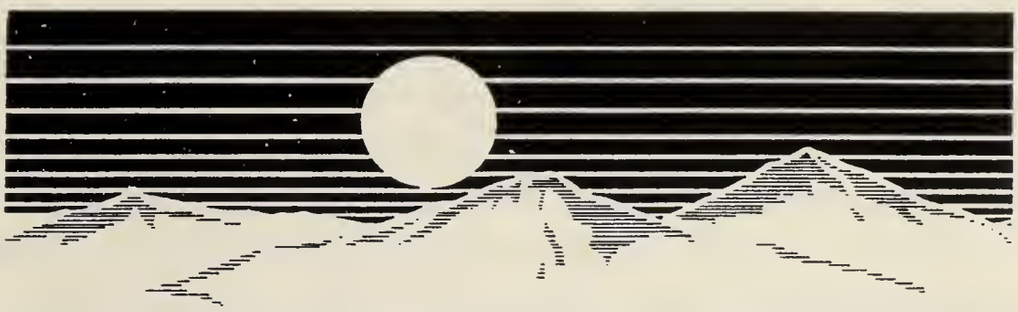

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Volume I - Report
October 1989

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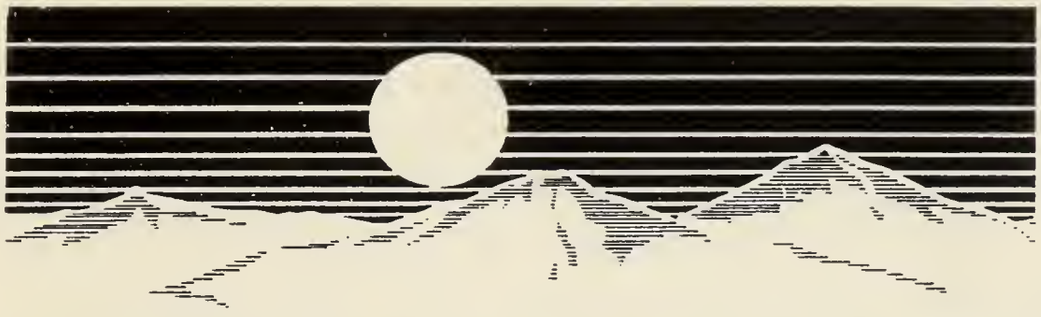

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PREFACE

This feasibility study was prepared by the Montana Department of Health and Environmental Sciences (MDHES) with technical and engineering assistance by the engineering firm CH2M HILL. The study was conducted in cooperation with the U.S. Environmental Protection Agency (USEPA), in accordance with the requirements of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) or "Superfund" and the regulations promulgated thereunder. CERCLA allows states and the federal government to respond to releases and threatened releases of hazardous substances, pollutants, and contaminants.

This study identifies and evaluates remediation alternatives for the Warm Springs Ponds Operable Unit, near Warm Springs, Montana. The Warm Springs Ponds Operable Unit is a part of the Silver Bow Creek Superfund Site, which is one of four separate but contiguous Superfund sites in the upper Clark Fork Basin area of Montana. The Silver Bow Creek Site begins in Butte, Montana, and extends down Silver Bow Creek to its confluence with the Clark Fork River. The Clark Fork Basin then extends down the Clark Fork River to Milltown Dam. The Silver Bow Creek Site was placed on the Superfund National Priorities List in September 1983 after preliminary investigations and assessments were conducted at the site.

All of the chapters in this feasibility study are the result of the cooperative efforts of the State of Montana, the USEPA, and the engineering firm. The discussions of legal and procedural matters, and the discussions of the

applicable or relevant and appropriate requirements (ARARs) that any remedial actions will have to follow, are conclusions of the two agencies.

The agencies developed cleanup goals and provided direction and guidance for developing alternatives that would meet Superfund statutory requirements, ARARs, and current USEPA feasibility study guidance. The engineering firm provided technical support to the agencies to meet these objectives. MDHES and USEPA will ultimately select the remedy for this operable unit.

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LIST OF ABBREVIATIONS

ac-ft	acre-feet
AIC	acceptable intake chronic
AMC	Anaconda Minerals Company
ARARs	applicable or relevant and appropriate requirements
ARCO	Atlantic Richfield Company
ARM	Administrative Rules of Montana
As	arsenic
$CaCO_3$	calcium carbonate
Cd	cadmium
CDI	chronic daily intake
CFR	Code of Federal Regulations
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980 ("Superfund")
cfs	cubic feet per second
CH2M HILL	CH2M HILL CENTRAL, INC. (environmental engineering consultants for the OUFS)
Cu	copper
cu yd	cubic yard
EIS	environmental impact statement
Ep Tox	Extraction Procedure Toxicity Test
°F	degrees Fahrenheit
Fe	iron
Fed. Reg.	Federal Register
fps	feet per second
FS	feasibility study
g	gram. acceleration due to gravity
gpd/ft^2	gallons per day per square foot
GW	groundwater
hp	horsepower
ID	inside diameter
IECO	International Engineering Company
kg	kilogram
l	liter
MCA	Montana Code Annotated
MCE	maximum credible earthquake
MCL	maximum contaminant level
MDNRC	Montana Department of Natural Resources and Conservation

mg/kg	milligram per kilogram
mg/l	milligram per liter
Mn	manganese
MDHES	Montana Department of Health and Environmental Sciences
MDFWP	Montana Department of Fish, Wildlife, and Parks
MPDES	Montana Pollution Discharge Elimination System
msl	mean sea level
N/A	not applicable
NCP	National Contingency Plan
ng/l	nanograms per liter
NPDES	National Pollution Discharge Elimination System
NPL	National Priorities List
NTS	not to scale
O & M	operation and maintenance
OU	operable unit
OUFS	operable unit feasibility study
pb	lead
pH	standard measure of the hydrogen ion concentration (logarithmic)
PHEA	Public Health and Environmental Assessment
PMF	probable maximum flood
ppb	parts per billion
ppm	parts per million
RCRA	Resource Conservation and Recovery Act
RfD	reference dose
RI	remedial investigation
ROD	Record of Decision
SO_4	sulfate
SRT	solids retention time
TBCs	To be considereds
TCL	Target Compounds List
TSDF	treatment, storage, and disposal facility
ug/l	micrograms per liter
umho/cm	micromhos per centimeter
USC	U.S. Code
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
WSP	Warm Springs Ponds
WSPOU	Warm Springs Ponds Operable Unit
yd	yard
XRF	X-ray fluorescence
Zn	zinc

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GLOSSARY OF TERMS

Acre-Foot: The amount of water it takes to cover an acre of land with 1 foot of water. Equal to 325,829 gallons.

Acceptable Daily Intake: The amount of a toxic substance that is without appreciable risk of causing an adverse effect to the general human population following exposure. The amount is derived from human and/or animal studies, with a safety factor applied to account for the level of confidence in the data. Acceptable daily intake is expressed in milligrams of substance/kilogram body weight/day.

Acceptable Intake for Chronic Exposure: The highest human intake of a chemical that is not expected to cause adverse effects when exposure exists over a lifetime. The level usually is based on chronic animal exposure. Acceptable intake for chronic exposure is expressed in milligrams of chemical/kilogram of body weight/day.

Acute Standards: State water quality regulations setting peak short-term concentrations of contaminants to prevent injury or death of aquatic life. They are derived from federal Ambient Water Quality Criteria. (See chronic standards for comparison.)

Alternative Treatment Technologies: Treatment technologies that have been fully developed but are not yet extensively used, such as bioremediation, certain incineration technologies, etc.

Applicable or Relevant and Appropriate Requirements: Federal and state environmental laws that legally apply or are relevant and appropriate to site cleanup. (See CERCLA §121(d), 42 USC §121(d).)

Background Levels or Concentrations: Typical concentrations of various metals and other chemicals, measured by Moore (1985), in areas in the Clark Fork Basin near Missoula and Milltown. These values are used in this feasibility study only as current baseline concentrations for comparison with contaminant concentrations of soils in the operable unit.

Baseflow: The sustained flow of a stream that is fed primarily by groundwater. Low flows during low precipitation/runoff periods (winter and summer) are primarily baseflow.

Chronic Standards: State water quality regulations setting maximum acceptable concentrations of contaminants for long-term protection of aquatic life. They are derived from federal ambient water quality criteria. (See acute standards for comparison.)

Clean Water Act: The Federal Water Pollution Control Act, 33 USC §§ 1251-1387, enacted to restore and maintain the chemical, physical, and biological integrity of the nation's waters by controlling discharges of pollutants and dredged or fill materials into those waters.

Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA): The statutory program to clean up existing hazardous waste sites and to provide a response mechanism to clean up release of such wastes into the environment. 42 USC §§ 9601-9675. (See Superfund.)

Cubic Feet Per Second (CFS): A measurement of volume flow rate equivalent to 646,315.2 gallons per day and 1.98 acre-feet per day.

EP Toxicity: A characteristic of waste, as determined by testing involving an extraction procedure, that shows concentrations of specified contaminants, primarily heavy metals and certain pesticides. Wastes that are EP toxic are classified as hazardous wastes and are subject to strict handling and disposal requirements. Section 16.44.324, ARM; 40 CFR § 261.24.

Exposure Pathway: Defines the ways potential human receptors (residents, visitors, workers, etc.) could be exposed to contaminated site media (water, soil, biota, etc.).

Exposure Scenario: Characterizes the amount of contaminated media consumed, inhaled, or absorbed by quantifying each potential receptor/media/exposure pathway combination for the site.

Feasibility Study: The study undertaken by the U.S. Environmental Protection Agency or the Department of Health and Environmental Sciences to develop and evaluate remedial action alternatives under Superfund in order to select the proper remedy. Remedial action alternatives developed in the feasibility study rely in part on data collected and analyzed in the remedial investigation.

Hazard Index: A system for assessing the overall potential for adverse health effects posed by exposure to multiple noncarcinogenic chemicals. The hazard index is expressed numerically and indicates the proximity of a chemical mixture to acceptable exposure limits or the degree to

which a mixture exceeds acceptable exposure levels. A hazard index greater than one for a particular substance or mixture indicates a potential health risk from the mixture. The hazard index provides only a rough measure of the toxicity of a mixture.

Human Health and Environmental Protectiveness Standards: Standards used to assess the adequacy of cleanup alternatives if applicable or relevant and appropriate requirements do not exist or do not adequately protect public health and the environment. For example, cleanup standards for soil are based on the risk posed by exposure to contaminants in soil, because no federal or state law defines acceptable concentration limits.

Lead Agency: The governmental agency with primary responsibility for coordinating response actions and/or enforcement activities at a Superfund site. 40 CFR § 330.6 (1985). The Montana Department of Health and Environmental Sciences is the lead agency for purposes of conducting remediation at the Silver Bow Creek Site, including the Warm Springs Ponds Operable Unit. MDHES and EPA will jointly select the remedy and take appropriate enforcement action.

Maximum Contaminant Levels: Water quality standards adopted pursuant to the federal Safe Drinking Water Act, signifying the maximum permissible level of a contaminant in drinking water. 42 USC § 300f(3).

Maximum Credible Earthquake: The most severe earthquake considered to be possible at Warm Springs Ponds on the basis of geological and seismological evidence. The maximum credible earthquake is determined by regional and local studies, which include a complete review of all historic earthquake

data relating to events sufficiently nearby to influence the site, all faults in the area, and attenuations from causative faults to the site. The maximum credible earthquake has not been established for the Warm Springs Ponds, although a preliminary estimate is available for use in this study.

Media-Specific Action: A remedial action (i.e., cleanup) alternative for a specific medium, such as surface water, groundwater, or soil. Media-specific actions ultimately are combined into comprehensive cleanup alternatives addressing all media at the operable unit.

Montana Water Quality Act: The Montana law established to prevent, abate, and control pollution of state waters so as to protect and improve the quality and potability of water for drinking, aquatic habitat, agriculture, recreation, and other beneficial uses. Title 75, Chapter 5, MCA.

National Contingency Plan: The National Oil and Hazardous Substances Pollution Contingency Plan, published under the Clean Water Act, revised pursuant to CERCLA, and set forth at 40 CFR Part 300 (1985). The NCP provides comprehensive guidelines and procedures for efficient, coordinated, and effective response to discharges of oil and releases of hazardous substances, pollutants, and contaminants. 40 CFR § 300.3(b) (1985).

National Priorities List: CERCLA requires the President to prepare a list of national priorities among Superfund and potential Superfund sites for the purpose of taking remedial or removal action to respond to releases or threatened releases of hazardous substances at such sites. The list is used to determine what sites will be accorded priority for cleanup using Superfund money. 42 USC § 9605(a) (8) and 40 CFR § 300.66(c) (1985).

No-Action Alternative: A remedial action alternative that involves taking no or very minimal action at a site. A no-action alternative generally provides a basis from which to compare action alternatives by illustrating the risks to human health and the environment existing at a site without remediation.

100-Year Flood: A flood magnitude expected to recur on the average of once every 100 years or a flood magnitude that has a 1 percent chance of occurring in any given year.

Operable Unit: A portion of a Superfund site, addressing either geographical areas of the site, specific site problems, or other discrete components of the site. Any given site can be divided into a number of operable units. 40 CFR § 300.6 (1985); Proposed Revision to NCP, 53 Fed. Reg. 51,394 (1988) (to be codified at 40 CFR § 300.5). The Warm Springs Ponds Operable Unit is one of several operable units of the Silver Bow Creek Site.

Preliminary Assessment and Site Investigation: The initial evaluation of potential hazards to health or the environment caused by hazardous substances at a site. The preliminary assessment is conducted by the lead agency to determine the source and nature of the release, whether a threat to public health or the environment exists, the need for cleanup activities, and whether the site should be listed on the National Priorities List. 40 CFR § 300.64 (1985).

Primary Drinking Water Standards: Standards established pursuant to the Safe Drinking Water Act that apply to public water systems, specify contaminants that may adversely affect human health, and specify acceptable

contaminant levels (in terms of maximum contaminant levels). 42 USC § 300f(1).

Probable Maximum Flood (PMF): The most severe flood that may be reasonably expected in a particular location, as determined by a combination of regional meteorologic and hydrologic conditions.

Probable Maximum Precipitation: The greatest estimated depth of precipitation for a given duration that is physically possible over a given size storm area at a particular geographic location at a certain time of the year. The probable maximum precipitation is one factor used in assessing the probable maximum flood.

Public Health and Environmental Assessment: An analysis of existing and potential human health and environmental risks at a site, stated both quantitatively and qualitatively, resulting from exposure to contaminants. The public health and environmental assessment is based in part on information gathered during the remedial investigation. It provides one basis for determining whether remedial action is necessary at a site and estimates the health and environmental risks associated with selecting a no-action alternative. Equivalent to baseline risk assessment.

Record of Decision: Documentation of the alternative selected, if required, to clean up a site. Selection and implementation of the no-action alternative would not require a record of decision.

Remedial Action: A response to a release of hazardous substances to prevent or minimize the release so that it does not cause substantial danger to present or future public health or welfare or the environment. 42 USC

§ 9601(24) and 40 CFR §§ 300.6 and 300.68 (1985).

Remedial Action Alternatives: Options for conducting remedial action (i.e., cleanup) at a site. The alternatives in this feasibility study are developed first on a media-by-media basis. Alternatives to provide cleanup of a medium are called media-specific actions. Media-specific actions are then combined into comprehensive cleanup alternatives, called operable unit-wide alternatives, providing cleanup remedies for all media at the operable unit.

Remedial Design: The stage in the Superfund cleanup process, following selection of a remedy in the record of decision, during which detailed design plans and specifications are developed to implement the cleanup. Following the remedial design phase, the selected cleanup actions are implemented.

Remedial Investigation: A study and assessment of the nature and extent of actual and threatened contamination at a Superfund site, based on field investigations, laboratory analyses, and data evaluations. Data obtained through the remedial investigations are used in conjunction with other data to develop remedial action alternatives for a site, which are presented and evaluated in the feasibility study.

Resource Conservation and Recovery Act (RCRA): The statutory scheme to regulate hazardous waste management from "cradle-to-grave," including the treatment, storage, and disposal of such wastes. 42 USC §§ 6901-6991i.

Resource Recovery Technologies: Technologies that recover energy or material resources from waste. Resource recovery technologies can be used for cleanup at some sites.

Safe Drinking Water Act: The statutory scheme regulating contaminant levels in water used for drinking purposes in order to ensure protection of public health. 42 USC §§ 300f - 300j-11.

Secondary Drinking Water Standards: Standards established pursuant to the Safe Drinking Water Act that apply to public water systems. They differ from primary drinking water standards principally in that they protect public welfare, as opposed to the health of persons. 42 USC § 300f(2).

Superfund: The Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), amended in 1986 by the Superfund Amendments and Reauthorization Act (SARA). 42 USC §§ 9601-75. The statutory program to clean up existing hazardous waste sites and to provide a response mechanism to clean up release of such wastes into the environment.

Support Agency: The governmental agency providing a review and consultative role to the lead agency in the conduct of technical and/or enforcement activities at a Superfund site. The support agency provides general oversight of activities, participates in the decisionmaking process, reviews and comments on technical data, and represents the interests of the agency. EPA has the role of support agency with respect to remedial activities at the Silver Bow Creek Site, including the Warm Springs Ponds Operable Unit. MDHES and EPA will jointly select the remedy and take appropriate enforcement action.

Target Compound List: EPA's Routine Analytical Services list of organic compounds.

Treatability Studies or Testing: Small-scale testing of a treatment alternative or unit operation of a treatment alternative to obtain performance evaluations and cost estimates in anticipation of full development and evaluation of the treatment alternative.

Water Quality Criteria: Water quality characteristics that are expected to support and protect an organism, an organism community, or a prescribed water use or quality with an adequate degree of safety. Criteria for domestic water supplies are intended to protect human health, whereas criteria for aquatic life are intended to protect aquatic ecosystems. Water quality criteria differ from water quality standards in that the former are not enforceable rules. Rather, criteria represent scientific data and guidance of the environmental effects of pollutants and are used to derive water quality standards (i.e., regulations).

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ERRATA AND LATE REVISIONS

Changes to report appear in bold-face type below:

Page 4-7 — Figure 4-2 should have the same notes as listed in Figure 4-1.

Page 7-22 — The second bulleted item should read, "Transportation to an onsite **secure** disposal facility (Pond 1 prior to solidification or capping **with a RCRA-equivalent cap**)

Page 7-76 — The end of fourth paragraph referring to capping should read, "...a stable vegetative cover **in accordance with reclamation requirements.**"

Page 7-82 — The end of the first paragraph referring to Pond 1 should read, "...**is to cover it with a RCRA-equivalent** cap and revegetate the contaminated areas."

The second paragraph states that "action levels for tailings deposits and contaminated soils have not yet been set. However, the "assumed" action levels have now "...been **selected...** " (as stated on page 7-1)

BKCVOR129/101.50

DRAFT

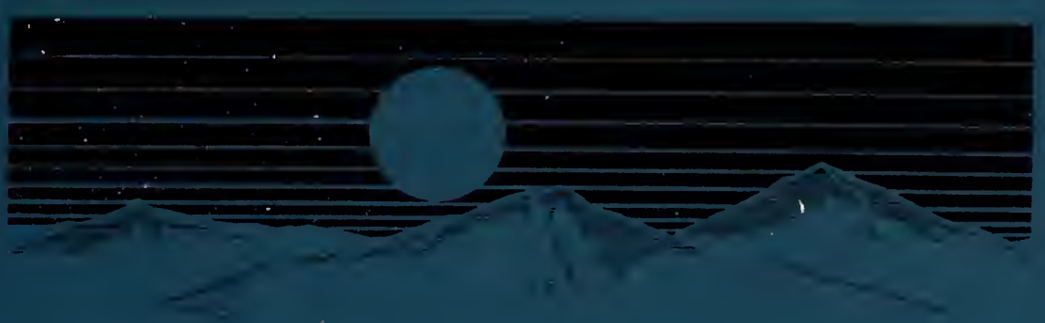
SILVER BOW CREEK INVESTIGATION

Feasibility Study

for the

Warm Springs Ponds Operable Unit

Montana Department
of
Health and Environmental Sciences
(MDHES)



Executive Summary

Prepared by
MDHES
CH2M HILL

DRAFT

October 1989

EXECUTIVE SUMMARY

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EXECUTIVE SUMMARY

INTRODUCTION

The Warm Springs Ponds are a part of the Silver Bow Creek Superfund Site. The ponds are located at the downstream end of Silver Bow Creek, just above the confluence of the Mill-Willow Bypass and Warm Springs Creek. That confluence is the defined beginning point of the Clark Fork River. Figure ES-1 shows the major features of the Warm Springs Ponds Operable Unit and establishes the boundaries of the study area.

The Clark Fork Basin, which includes the Silver Bow Creek Site, is the largest geographic area in the nation being addressed under Superfund. The site has been impacted by over 100 years of mining and processing operations in the Butte and Anaconda areas. Mining began with the discovery of gold in 1864 on Silver Bow Creek. By 1884, the Butte area contained over 300 combined copper and silver mines, 9 silver mines, and 8 smelters. Mining and smelting continued until 1982, when the Anaconda Minerals Company, by that time owned by the Atlantic-Richfield Company, closed the Berkeley Pit in Butte. Mining and milling has since resumed, with the takeover of operations by Montana Resources, Inc., and others in 1986.

Over the years, the mining and related activities have resulted in extensive soil, water, and air contamination within the study area. Contamination of Silver Bow Creek occurred from the outset of mining activities. Mining, milling, and smelting wastes were dumped directly into

Silver Bow Creek and transported downstream to the Clark Fork River.

In 1911, the Anaconda Copper Mining Company built its first treatment pond near Warm Springs, Montana, to settle out wastes from Silver Bow Creek before the water reached the Clark Fork River. This is now noted as Warm Springs Pond 1 (see Figure ES-1). Warm Springs Ponds 2 and 3 were constructed in approximately 1916 and 1959, respectively, as additional settling capacity was needed. The ponds now cover an area of approximately 4 square miles. Over the past 80 years, an estimated 19 million cubic yards of tailings and heavy metal contaminated sediments (sludges) have collected in the ponds. The 19 million cubic yards of wastes could cover the playing area of 100 football fields 90 feet deep, which is as high as a nine-story building.

Mining wastes are no longer released directly into Silver Bow Creek, but tailings deposits along the creek banks continue to erode and travel down the creek during periods of above-average flows and floods. It is estimated that approximately 3 million cubic yards of contaminated tailings are still present along the banks of Silver Bow Creek. Through dissolution, the tailings and sediments cause the water flowing in Silver Bow Creek to be contaminated with dissolved metals, particularly copper and zinc. Other metals detected in Silver Bow Creek are arsenic, cadmium, lead, iron, aluminum, and manganese.

The Warm Springs Ponds are still used to contain entrained sediments and treat the contaminated water flowing down Silver Bow Creek before it reaches the Clark Fork River. The ponds operate by settling out tailings particles and other solids and by reducing the concentrations of the

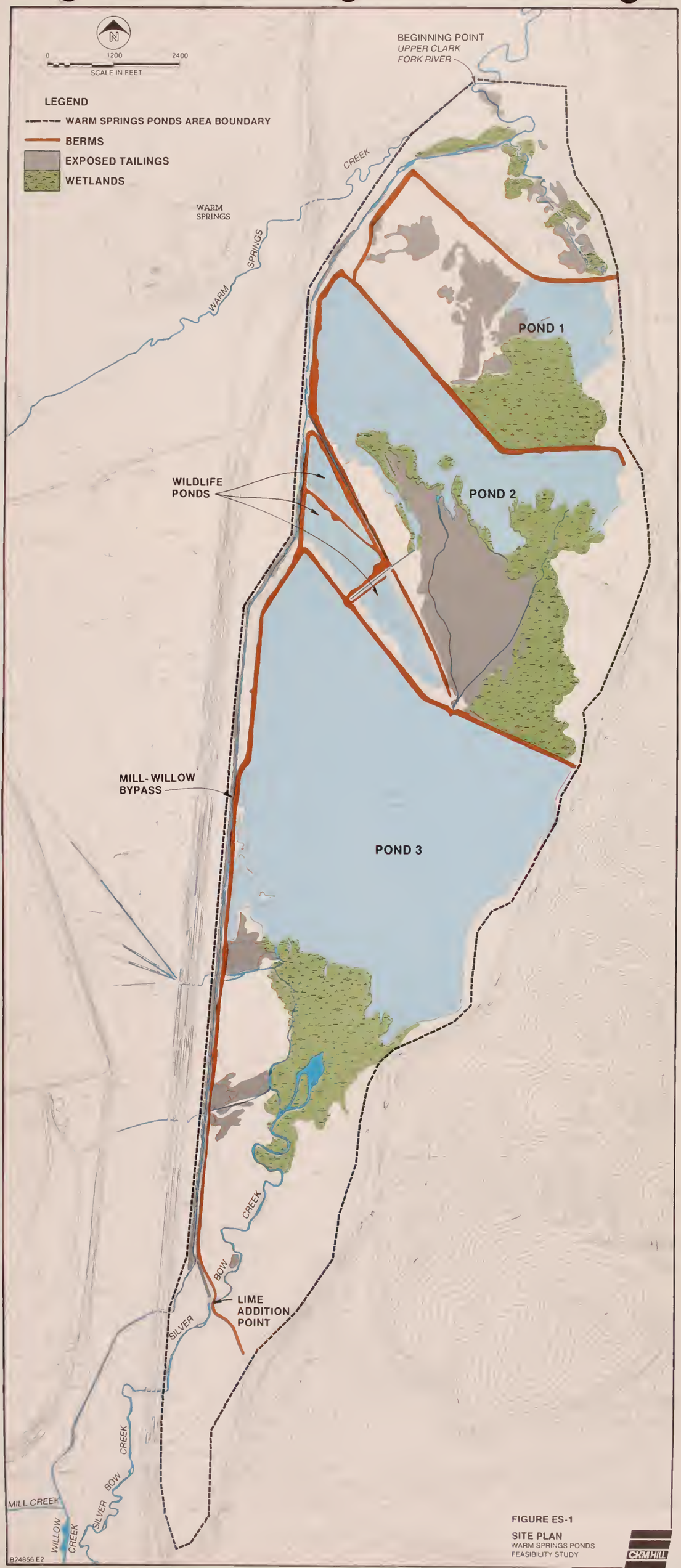

FIGURE ES-1

SITE PLAN
WARM SPRINGS PONDS
FEASIBILITY STUDY

CH2MHILL

dissolved metals. Chapter 2, Site Description and Contamination Characteristics, of this feasibility study describes the operation of the Warm Springs Ponds in detail.

The berms containing the Warm Springs Ponds are susceptible to flood and earthquake damage. Failure potentially could release millions of cubic yards of the tailings and sediments into the Clark Fork River. Because this could cause considerable environmental damage downstream of the ponds, the State of Montana and the USEPA identified the ponds as a high-priority portion of the Silver Bow Creek Superfund Site and the first operable unit of the site to be studied.

The Warm Springs Ponds Operable Unit also presents two other significant environmental and human health concerns:

- The surface waters in all three creeks that enter the operable unit (Mill, Willow, and Silver Bow; see Figure ES-1) are contaminated with dissolved metals. The surface water quality standards adopted under the Montana Water Quality Act are frequently exceeded for copper and zinc within the area.

- Large areas of surface contamination, comprised of tailings and contaminated soils, are present within the boundaries of the Warm Springs Ponds Operable Unit. The tailings and contaminated soils, which include previously submerged pond bottom sediments that are now exposed, contain elevated levels of several metals and are partially unvegetated or sparsely vegetated. The exposed tailings and contaminated soils are available for human and

animal exposure. Copper and zinc, which are significant contaminants in the tailings, are suspected of causing several fishkills observed in the Mill-Willow Bypass and the Clark Fork River. Tables 2-2 and 2-3 list the metals identified in the deposits at several areas around the site.

This feasibility study relies on and incorporates data and information developed during the site remedial investigation. The remedial investigation studied the nature and extent of contamination existing within the operable unit. The purpose of this feasibility study is to develop a range of feasible alternatives for site cleanup. It develops and evaluates in detail a range of remedial alternatives from which the State of Montana and the USEPA, with public participation, will select the appropriate remedy for site cleanup. The selected cleanup alternative must, at a minimum, ensure protection of human health and the environment and meet certain applicable or relevant and appropriate requirements, standards, criteria, or limitations.

THE FEASIBILITY STUDY PROCESS

Superfund and the National Contingency Plan establish a process and a format for site investigations, remedy selection, and site cleanup (see Figure ES-2). First, a preliminary assessment and a subsequent remedial investigation explore the nature and extent of contamination at the site. A determination is made whether site conditions require immediate cleanup work to protect public health and the environment, and whether the site warrants further remedy.

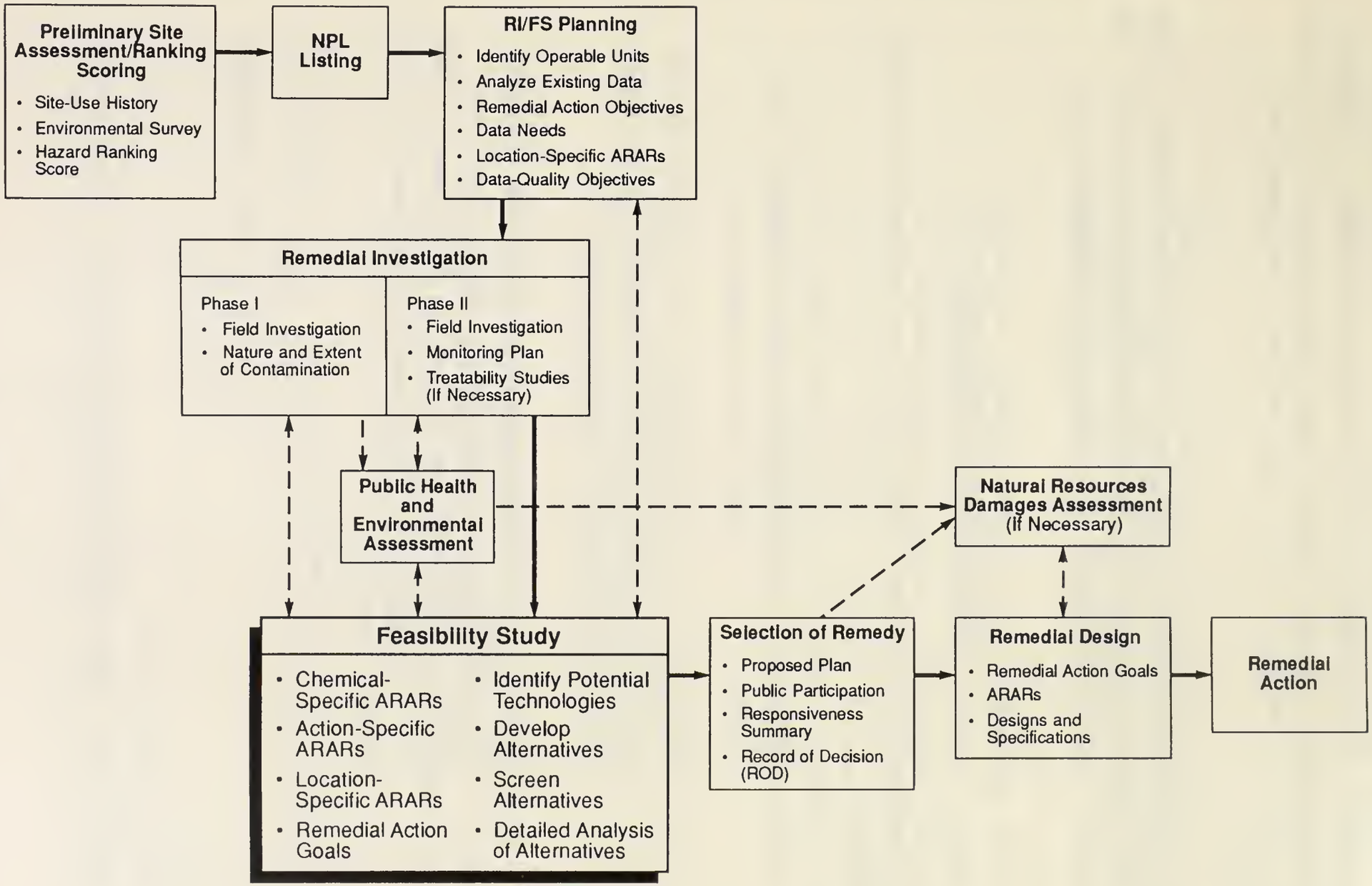

FIGURE ES-2

THE SUPERFUND PROCESS
WARM SPRINGS PONDS OPERABLE UNIT
FEASIBILITY STUDY

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The USEPA conducted preliminary site investigations and assessments of the Upper Clark Fork Basin in 1982. A remedial investigation for the Warm Springs Ponds was conducted under the State of Montana's direction and was completed in 1989.[1]

The feasibility study is the next step in the process. This study will be followed by the decisionmaking process for the selected remedy, followed by design and implementation.

ORGANIZATION OF THE REPORT

The results of the feasibility study are presented in eight chapters:

- Chapter 1: Introduction and background of the study
- Chapter 2: Site description and summary of the nature and extent of the contamination as determined by the remedial investigation
- Chapter 3: Summaries of applicable or relevant and appropriate requirements (ARARs) and the Public Health and Environmental Assessment (PHEA), both of which will determine the nature and scope of the cleanup

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[1] CH2M HILL, 1989. Phase II Remedial Investigation Data Summary. Prepared for the State of Montana Department of Health and Environmental Sciences, Helena, Montana.

- Chapter 4: Listing and description of eight specific public health and environmental problems identified within the Warm Springs Ponds Operable Unit

- Chapter 5: Presentation of remedial objectives for the Warm Springs Ponds Operable Unit and identification of general approaches that might be taken to achieve those objectives

- Chapter 6: Identification and screening of specific remedial technologies and process options for implementing the general approaches identified in Chapter 5, selection of representative remedial technologies and process options for use in assembling media-specific actions, and assembling media-specific actions for the eight human health and environmental problems

- Chapter 7: Engineering development of the media-specific actions into conceptual approaches for meeting the remedial objectives

- Chapter 8: Assembly of a range of remedial alternatives by combining media-specific actions, and evaluation of the alternatives against seven criteria specified by the USEPA

The remainder of this Executive Summary briefly summarizes the results of the study on a chapter-by-chapter basis, beginning with Chapter 2.

SITE DESCRIPTION AND CONTAMINATION CHARACTERISTICS

(Chapter 2)

The remedial investigation of the Warm Springs Ponds Operable Unit was completed in two phases. The Phase I remedial investigation was conducted by MultiTech from 1985 to 1987. The Phase II remedial investigation was conducted by CH2M HILL from 1987 to 1989.

SURFACE HYDROLOGY

The Warm Springs Ponds include the primary hydrologic features within the operable unit. They cover an area of approximately 2,500 acres (about 4 square miles). Three creeks from the south and the west flow through the operable unit (see Figure ES-3). Silver Bow Creek, the longest of the three creeks, flows from the south and enters Pond 3 near the southern end of the operable unit. Mill and Willow Creeks from the west and south flow into the Mill-Willow Bypass, a diversion ditch, which routes the comparatively less contaminated water in these two creeks around the ponds and to the Clark Fork River.

Water flowing out of Pond 3 goes primarily into Pond 2, with a smaller volume being used to maintain several wildlife ponds (see Figure ES-1). The effluent from Pond 2 flows into the Mill-Willow Bypass and then down the bypass to the Clark Fork River. The average flows in the three creeks are 73 cubic feet per second (cfs) for Silver Bow Creek, and 27 cfs for combined Mill and Willow Creeks.

The average flow of 100 cfs in the lower portion of the Mill-Willow Bypass is joined by the average flow of approximately 47 cfs in Warm Springs Creek at the northern end of the

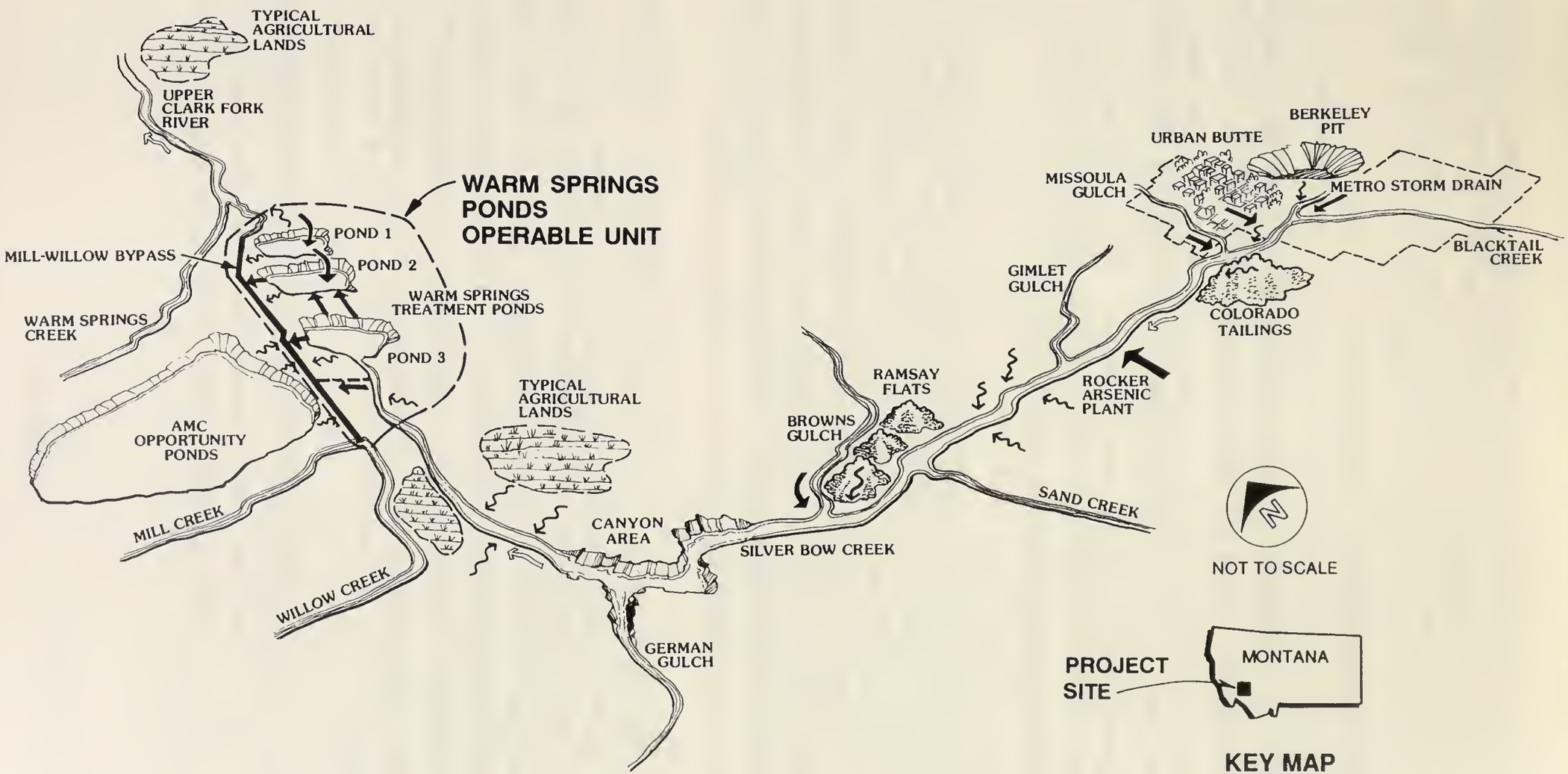

FIGURE ES-3

SILVER BOW CREEK SITE SCHEMATIC
WARM SPRINGS PONDS FEASIBILITY STUDY

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operable unit to form the Clark Fork River. (Warm Springs Creek is also contaminated, possibly due to milling and smelting activities in the area west of the operable unit.)

GROUNDWATER HYDROLOGY

The shallow groundwater system in the Warm Springs Operable Unit is complex, owing to the heterogeneity of the near surface geology in the area. The site is in a groundwater discharge area for the upper Deer Lodge Valley, typified by shallow groundwater tables and swamps. The presence of the pond system affects shallow groundwater elevations and groundwater movement within the site.

Shallow aquifers occur along present-day stream channels but do not extend laterally throughout the site. Deeper aquifers are associated with Tertiary-age valley fill and thick deposits of glaciofluvial material. These aquifers generally exhibit moderate to low permeabilities and are probably connected on a regional scale, although fine-grained interbeds tend to confine the deeper aquifers locally.

The uppermost aquifer at the site is a 10- to 15-foot-thick sand and gravel unit, which is typically present approximately 10 feet below ground surface. This sand and gravel aquifer appears to be present throughout most of the site. Groundwater movement through the site is generally south to north, although a significant component of groundwater enters from the Opportunity Ponds area to the southwest (see Figure ES-3).

No domestic wells are located within the Warm Springs Ponds Operable Unit. Several are located east of the pond system within a mile of the operable unit, but these wells are com-

pleted in bedrock aquifers that do not appear to be affected by the pond system. The town of Warm Springs derives its water from supply wells constructed in unconsolidated Tertiary deposits, from depths of approximately 200 feet. These wells appear to be supplied with water derived from groundwater resources west of and hydraulically isolated from the Warm Springs Ponds. (See Appendix A for more detailed information on groundwater use in the area.)

NATURE AND EXTENT OF CONTAMINATION

Sediments, surface water, soils, and groundwater are all affected by contaminants in the Warm Springs Ponds Operable Unit. A schematic that shows the contaminated areas and the migration pathways is presented as Figure ES-4. Four contaminated media have been identified for the operable unit: pond bottom sediments, surface water, tailings deposits and contaminated soils, and groundwater. The media are discussed in the following sections. Table ES-1 presents a breakdown of the areas and volumes for each of the four media.

Sediments, Tailings, and soils

Two of the media--the pond bottom sediments, and the tailings deposits and contaminated soils--contain the majority of the contaminants in the Warm Springs Ponds Operable Unit. These materials are typically fine to coarse sand and generally contain metals associated with the sulfide ore body present near Butte. Pond bottom sediments are also comprised of precipitated hydroxides and oxyhydroxides resulting principally from the addition of lime to treat the water

Table ES-1
SUMMARY OF AREAS AND VOLUMES OF MEDIA

	Area (acres)	Volume (acre-feet)	Volume (cubic yards)
Media 1--Pond Bottom Sediments			
Pond 1			
Exposed Sediments	59	455	734,000
Vegetated/Submerged Sediments	225	1,340	2,156,000
	284	1,795	2,890,000
Pond 2			
Exposed Sediments	155	800	1,300,000
Vegetated/Submerged Sediments	347	2,230	3,590,000
	502	3,030	4,890,000
Pond 3			
Submerged Sediments	665	6,930	11,180,000
Total Pond Bottom Sediments	1,451	11,755	18,960,000
Media 2--Surface Water			
Silver Bow Creek[a]			
Mill and Willow Creeks[b]			
Media 3--Tailings Deposits and Contaminated Soil			
Mill-Willow Bypass			
Exposed Tailings	21	47	75,800
Vegetated Tailings and Contaminated Soil	33	80	130,000
	54	127	205,800
Area Above Pond 3			
Exposed Tailings	22	56	90,300
Vegetated Tailings and Contaminated Soil	268	700	1,130,000
	290	756	1,220,300
Area Below Pond 1			
Exposed Tailings	17	48	77,400
Vegetated Tailings and Contaminated Soil	59	246	397,000
	76	294	474,400
Total Tailings Deposits and Contaminated Soil	420	1,177	1,900,500
Media 4--Groundwater[c]			
Area of contaminated aquifer beneath and downgradient of Pond 1	180		

[a]Flow ranges from 28-112 cfs (73 cfs average). Data collected from March 1985 to August 1985.
[b]Flow ranges from 3-87 cfs (27 cfs average). Data collected from December 1984 to August 1985.
[c]Exceedances of primary maximum contaminant levels for arsenic and cadmium.

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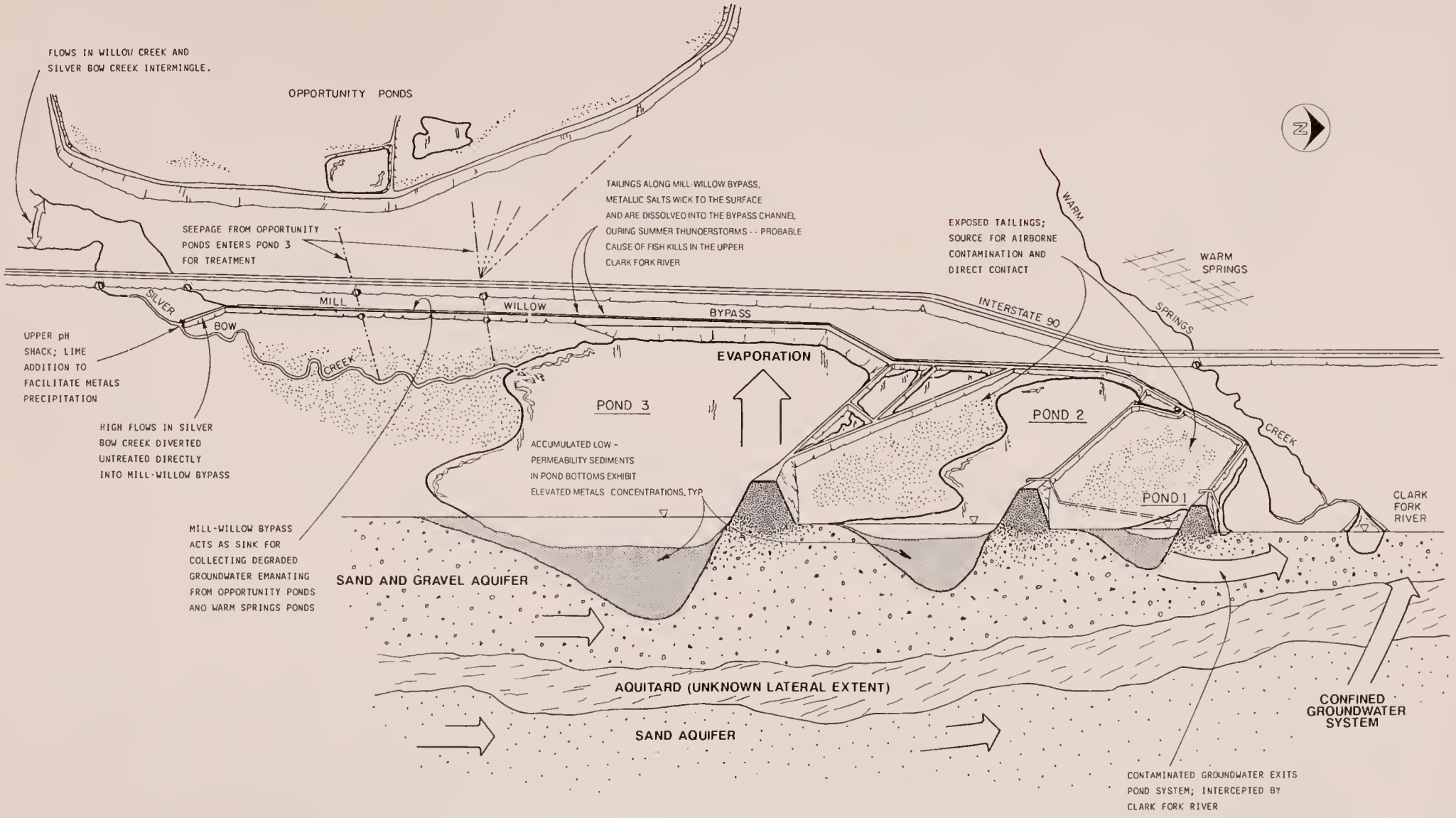

FIGURE ES-4

CONCEPTUAL MODEL OF CONTAMINANT MIGRATION PATHWAYS
WARM SPRINGS PONDS
FEASIBILITY STUDY

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entering the pond system and from biologically mediated precipitation.

The exposed (unsubmerged) sediments, tailings deposits and contaminated soils cover an area of approximately 634 acres within the Warm Springs Ponds Operable Unit. Thicknesses of these deposits range from less than 1 inch to several feet. The submerged sediments in Ponds 1, 2, 3, and the wildlife ponds cover an area of approximately 1,227 acres and range in thickness from less than 1 foot to over 20 feet (Table ES-1)

Surface Water

The data obtained during the remedial investigation characterize the surface water for near-average flow rates. Few data are available to characterize the surface water quality during higher flows because of drier-than-normal conditions in the area experienced during the remedial investigation. No opportunity was available during the sampling period to collect flow and contamination data during one of the high runoff events that cause inflows to be diverted around the pond system.

Surface water samples were collected at 25 sampling points in and adjacent to the Warm Springs Ponds Operable Unit during Phase I and Phase II remedial investigations. The Phase I remedial investigation showed that metals are being removed from the Silver Bow Creek flow by the current pond treatment system. Inflow loads of total copper and total zinc were reduced by over 90 percent by the time the water left the pond system during the summer months and by 50 to 70 percent during winter months. Although metals concentrations are reduced in the pond system, Montana's chronic

ambient water quality standards for copper, lead, and zinc were exceeded throughout the operable unit including the pond system and the water leaving the pond system. Ambient standards for cadmium to protect aquatic life and for iron to protect public health were also frequently exceeded during the sampling events. Tables 2-8 through 2-11 give detailed summaries of the surface water quality data obtained in the remedial investigation.

Four 24-hour, or diurnal, sampling episodes were completed within the Warm Springs Ponds system during the Phase II remedial investigation to gain a better understanding of changes in water quality over 1-day periods and on a seasonal basis. These sampling episodes were completed in September 1987 and in January, April, and July 1988.

Hourly data from the diurnal sampling studies have been compiled.[2]

The data for the 24-hour sampling episodes indicate the following:

- pH varied by up to 2.2 units throughout the day at all stations sampled.
- Total metals concentrations decreased 50 to 90 percent between pond system inflow and outflows.
- Dissolved metals concentrations for copper and zinc were generally 20 to 50 percent higher in the winter at all sampling stations in the pond system.

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2 Ibid.

Higher dissolved metals concentrations in the winter correlate directly with lower pH values measured during winter sampling events.

The pond system reduced metals concentrations at the outflows from the system during the four diurnal sampling events, frequently to levels below both chronic and acute aquatic standards. Figure ES-5 shows an example of this phenomenon recorded during one of the diurnal sampling events. Removal of metals in the ponds is accomplished by physical, biological, and chemical processes. Physical reduction of metal-bearing solids occurs through sedimentation. Increases in pH as a result of photosynthesis can precipitate metals as a result of changing metals solubilities. Another important mechanism may be precipitation of calcite and coprecipitation of metals and phosphorus as a result of photosynthetic removal of carbon dioxide and compensating shifts in the bicarbonate buffering system.[3] Direct uptake or absorption of metals by algae and aquatic macrophytes is also probable. Addition of lime to the Silver Bow Creek inflow during the winter months also contributes to precipitating metal contaminants when the amount of sunlight to support photosynthesis is reduced.

Several fishkills have occurred in the Mill-Willow Bypass and in the upper Clark Fork River, with the most recent being in July 1989. Analysis of fish tissue by Montana Department of Fish, Wildlife, and Parks from one event in the summer of 1986 revealed acute copper poisoning as the cause of the fish mortality. Although MDFWP did not determine the source of metals responsible for the killings, that source most likely consists of tailings material along the

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[3] Wetzel, R.G., 1975. Limnology. Philadelphia: W.B. Saunders Company.

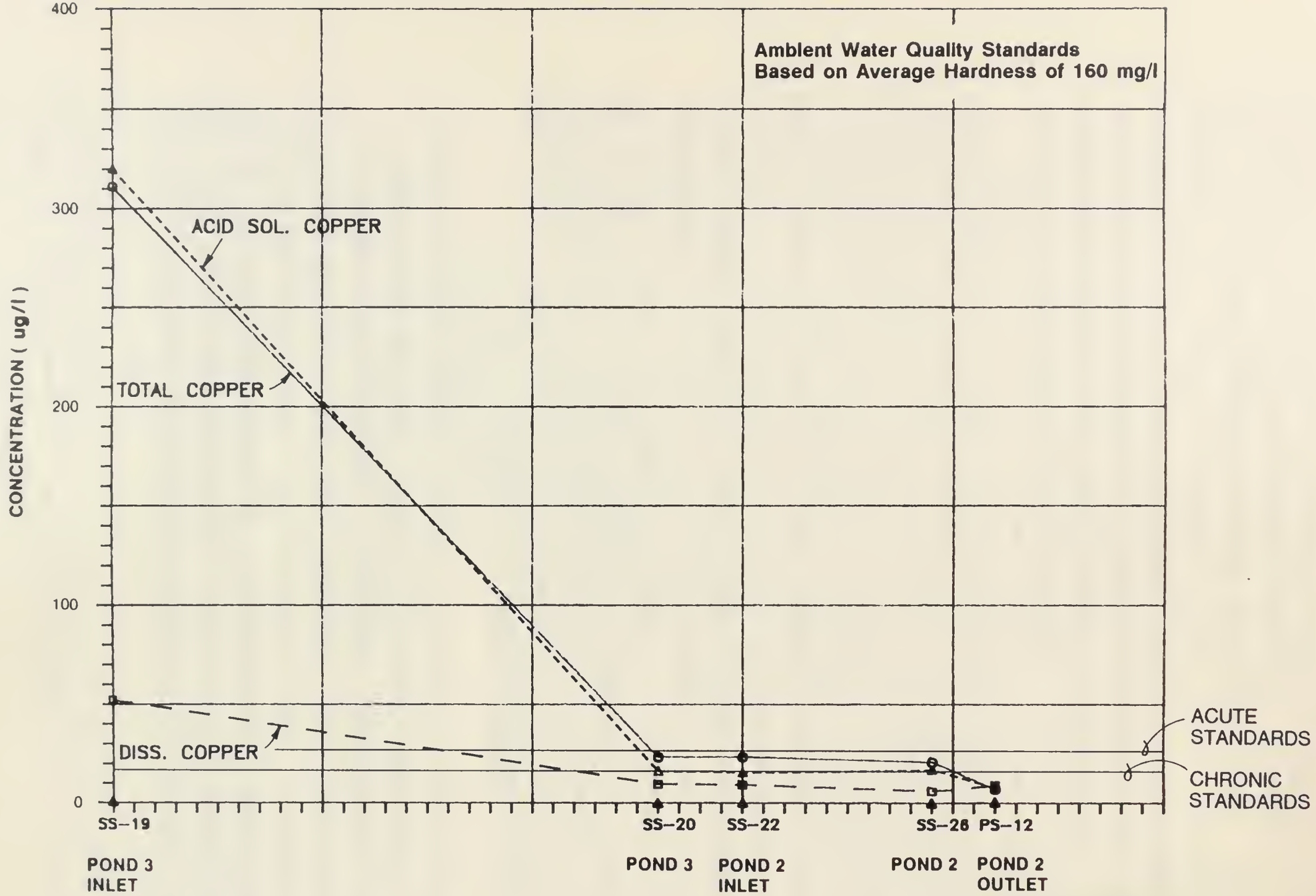

FIGURE ES-5

DECREASE IN COPPER CONCENTRATIONS THROUGH THE POND SYSTEM

WARM SPRINGS PONDS
FEASIBILITY STUDY

NOTE:
BASED ON PHASE II RI,
24 HOUR SAMPLING——SEPTEMBER 1987.

SOURCE: PHASE II RI REPORT; CH2M HILL 1989

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Mill-Willow Bypass. (See Chapter 4 for a detailed discussion of the probable cause of the fishkills.)

Groundwater

Groundwater quality data were generated through sampling of 19 monitoring wells on two occasions (January and May, 1988). Figure ES-6 shows the locations of the monitoring wells at the site. Table ES-2 summarizes groundwater quality data for these monitoring wells.

Groundwater beneath Ponds 2 and 3 may be contaminated also. Wells were not installed to determine the quality of the groundwater beneath those two ponds. Given the hydrogeology of the site, contaminated groundwater under the ponds would flow north and be detected at the northern end of the pond system.

With one exception, all detected exceedances of the Montana primary maximum contaminant levels for metals (arsenic and cadmium) were north of the Pond 1 berm. Groundwater quality downgradient of Pond 1 is generally of poorest quality immediately north of the berm; most metal contaminants decrease to the north, or downgradient of the pond system. Concentrations of most metals also decrease with depth.

Highest concentrations of metals are generally associated with the shallow sand and gravel aquifer in the area immediately below the Pond 1 berm.

Calculations of groundwater discharge from the area below Pond 1 into the Clark Fork River indicate that the groundwater system contributes very little flow to the river because of the relatively low permeability and low gradient

Table ES-2
GROUNDWATER QUALITY DATA SUMMARY
WARM SPRINGS PONDS OPERABLE UNIT

Parameter	Maximum Concentration[a]	Minimum Concentration[a]	Average Concentration[a]	Number of Samples	Maximum Contaminant Level[a] (Montana Groundwater Regulations
Upgradient Monitoring Wells					
Arsenic	6.8	2.6	4.3	8	50[b]
Cadmium	7.0	<5.0	3.4	8	10[b]
Copper	9.7	6.1	5.8	8	1,000[c]
Lead	1.2	<1.0	0.84	8	50[b]
Manganese	22.0	<3.0	7.3	8	50[c]
Zinc	21.2	4.7	10.3	7	5,000[c]
Iron	28.0	<15.0	19	8	300[c]
Sulfate (mg/l)	68.0	23	49	8	250[c]
Mill-Willow Bypass (Shallow Wells)					
Arsenic	41.0	<2.0	9.2	10	50[b]
Cadmium	11.7	<5.0	3.7	10	10[b]
Copper	15.0	<6.0	4.6	10	1,000[c]
Lead	18.0	<1.0	2.5	10	50[b]
Manganese	14,500	45	4,755	10	50[c]
Zinc	1,250	12.7	265	10	5,000[c]
Iron	4,000	25.0	805	10	300[c]
Sulfate (mg/l)	1,130	60.0	563	10	250[c]
Mill-Willow Bypass (Deep Wells)					
Arsenic	<2.0	<2.0	1.1	8	50[b]
Cadmium	5.2	<5.0	2.9	8	10[b]
Copper	7.1	<6.0	4.0	8	1,000[c]
Lead	2.0	<1.0	1.1	8	50[b]
Manganese	8,550	7.0	2,121	8	50[c]
Zinc	38.0	6.2	22.2	8	5,000[c]
Iron	70	<15	33	8	300[c]
Sulfate (mg/l)	1,060	92.0	494	8	250[c]
Downgradient of Pond 1 (Shallow Wells)					
Arsenic	197.0	<2.0	28.0	14	50[b]
Cadmium	12.7	<5.0	3.6	14	10[b]
Copper	15.9	<6.0	5.8	14	1,000[c]
Lead	<2.0	<1.0	2.0	14	50[b]
Manganese	31,600	309	10,297	14	50[c]
Zinc	253	16.3	89.0	14	5,000[c]
Iron	80,900	45	16,220	14	300[c]
Sulfate (mg/l)	1,620	250	950	14	250[c]
Downgradient of Pond 1 (Deep Wells)					
Arsenic	<3.0	<2.0	1.0	13	50[b]
Cadmium	8.4	<5.0	4.3	13	10[b]
Copper	<8.0	<6.0	3.5	13	1,000[c]
Lead	<2.0	<1.0	0.8	13	50[b]
Manganese	4,460	3.0	577	13	50[c]
Zinc	43	6.2	19.8	13	5,000[c]
Iron	409	<15	52	13	300[c]
Sulfate (mg/l)	1,150	55	531	13	250[c]

[a] All values in ug/l unless otherwise noted.
[b] Primary standard (based on health criteria).
[c] Secondary standard (based on suitability criteria).

Notes:
1. Upgradient wells include WSP-GW-01, 06, and 09 (Figure 2-8).
2. Shallow wells are generally less than 15 feet deep; deep wells are generally 25 to 40 feet deep.
3. Mill-Willow shallow wells include WSP-GW-07S, 08S, 15S, 16S, and 17 (Figure 2-8).
4. Mill-Willow deep wells include WSP-GW-07D, 08D, 15D, and 16D (Figure 2-8).
5. Shallow wells downgradient of Pond 1 include WSP-GW-02S, 03S, 05, 12S, 13S, 14S, and 19S (Figure 2-8).
6. Deep wells downgradient of Pond 1 include WSP-GW-02D, 03D, 04, 12D, 13D, 14D, and 19D (Figure 2-8).
7. Average values calculated using one-half detection limit, when applicable. January and May 1988 data.
8. Additional maximum contaminant levels are: mercury and compounds: 2; nitrate: 10,000; selenium and compounds: 10; and silver: 50.

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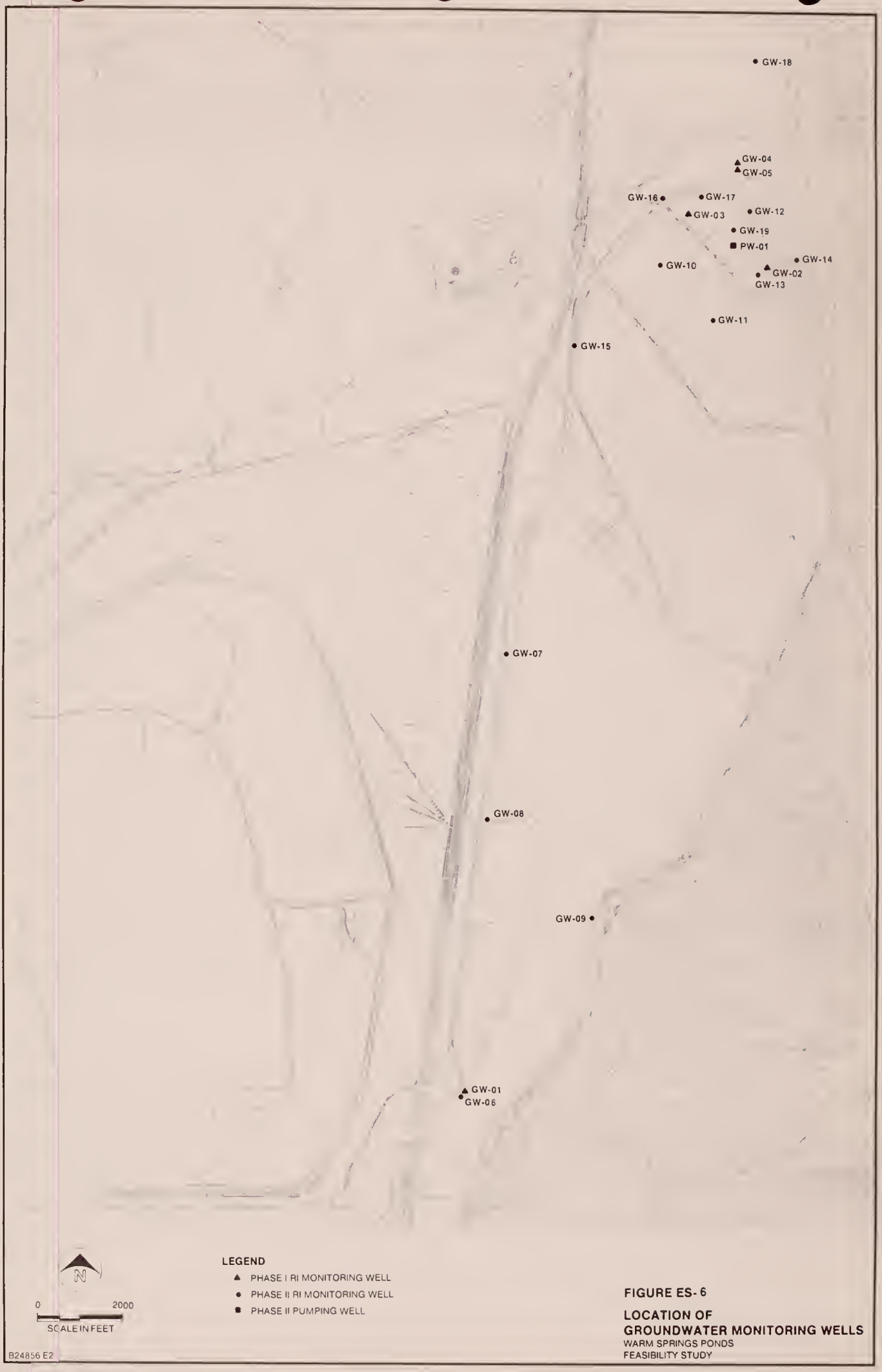

FIGURE ES-6

LOCATION OF GROUNDWATER MONITORING WELLS
WARM SPRINGS PONDS
FEASIBILITY STUDY

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of the shallow aquifer. Under average conditions, the flow in the Clark Fork River is approximately 137 cfs, while the groundwater discharge to the river is approximately 1.0 cfs.

The exceedances of the maximum contaminant levels for arsenic and cadmium in the groundwater constitute a violation of the drinking water standards that need to be addressed.

APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS, AND THE PUBLIC HEALTH AND ENVIRONMENTAL ASSESSMENT (Chapter 3)

APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARs)

The cornerstone of remedial actions undertaken through the Superfund program lies in the satisfaction of state and federal ARARs. ARARs are the basic standards by which all aspects of contaminant cleanup are measured. Chapter 8 evaluates potential compliance of the remedial alternatives with federal and Montana ARARs.

ARARs are divided into three categories: chemical-specific, location-specific, and action-specific. Chemical-specific ARARs include laws and regulations that set human health- or environmentally-based numerical values governing materials having certain chemical or physical characteristics. These values set the acceptable concentrations of chemicals that may be found in, or released to, the environment. Location-specific ARARs restrict contaminant concentrations or cleanup activities due to the site's geographic or physical location. Action-specific ARARs are based on actions taken during contaminant cleanup. Action-specific ARARs do not determine remedial alternatives; they indicate how the selected remedy must be achieved.

Chemical-Specific ARARs

The most significant state and federal chemical-specific ARARs consist of standards protecting the quality of surface and groundwater resources for human health and environmental purposes. Surface water ARARs include ambient water concentration limits to protect both aquatic life and public health, point source discharge standards for discharges from the pond system, and drinking water standards. Groundwater ARARs include only drinking water standards. The contaminants of concern at the site are arsenic, cadmium, copper, iron, lead, silver, selenium, mercury, aluminum, and zinc.

Location-Specific ARARs

Because the operable unit is located in the 100-year floodplain of local streams, the most significant location-specific ARARs regard land uses of the floodplain and construction in the floodplain. Other important location-specific ARARs include cleanup activity restrictions to protect and minimize impacts to heritage properties (the onsite ponds and an arched concrete bridge), a pair of bald eagles that have nested within the operable unit boundary, and wetlands.

Action-Specific ARARs

Action-specific ARARs pertinent to the Warm Springs Ponds Operable Unit include regulations concerning dam safety in event of floods and earthquakes, hazardous waste management, land reclamation for mining areas, and dredge or fill activities during site remediation.

Dam safety regulations address berm design and modification for the existing treatment system and for a proposed flood impoundment and sedimentation basin (see Chapter 7). Hazardous waste management ARARs include requirements for contaminant treatment, storage, and disposal. In particular, RCRA groundwater monitoring, closure, capping, and post-closure monitoring and maintenance may be required. Reclamation ARARs require proper grading, backfilling, subsidence stabilization, water control, topsoiling, revegetation and other measures needed in surface mining areas to eliminate damage from soil erosion, subsidence, landslides, water pollution, and hazards dangerous to life and property. Remedial actions that involve dredging local waterways or placing fill material in wetland areas will need to comply with requirements of Section 404 of the Clean Water Act, which ensure that dredging and filling activities will not have unacceptable adverse effects on wetlands, municipal water supplies, fishery areas, wildlife, or recreational areas in or affecting the waters of the U.S.

PUBLIC HEALTH AND ENVIRONMENTAL ASSESSMENT (PHEA)

The PHEA was conducted to determine the potential threat to human health and the environment posed by the operable unit in the absence of any remedial action. The no-action alternative assessed in the PHEA assumes the continuation of current site operations and conditions. The human health risk characterization of the site includes potential carcinogenic and noncarcinogenic health effects.

Health Risks

The contaminants of concern are metals or inorganic metal compounds. Potential human health risks from site metals were derived by standard Superfund protocol using

residential, occupational, and recreational exposure scenarios involving contaminated media (soils, sediments, water) and contamination within the food chain (waterfowl and fish). The PHEA exposure scenarios defined the amounts of contaminated media that could be consumed, inhaled, or absorbed by quantifying each potential receptor/media/exposure pathway combination for the site (Table ES-3). Important considerations in assembling an exposure scenario include exposure durations (days, months, years), exposure frequency (daily, weekly, etc.), age/weight of exposed persons, and environmental factors that can affect exposure (snow/rain can prevent dust generation, etc.). The scenarios assessed consider current site conditions and take into account potential future site developments (additional recreational use, new residential areas, etc.).

The maximum potential excess lifetime carcinogenic risks based on arsenic for all site media under the current recreational scenario is 8×10^{-5}. The maximum potential excess lifetime carcinogenic risks for all site media under the current occupational scenario is 2×10^{-4}. The maximum excess lifetime potential carcinogenic risk for all site media under the future residential scenario is 2×10^{-2}. No potential human health threat was identified from exposure to constituents with noncarcinogenic effects for the current recreational or the current occupational scenarios.

Under the current residential scenario, potential carcinogenic risks were identified only for the inhalation and ingestion of contaminated dust. At the town of Warm Springs, the calculated excess lifetime cancer risk for dust inhalation or ingestion ranged from 1×10^{-6} to 1×10^{-5}. At residences east of the operable unit, excess lifetime

Table ES-3
SUMMARY OF POTENTIAL "CLEANUP" GOALS
(MOST PROBABLE INTAKES THROUGH ALL EXPOSURE SCENARIOS)

Scenario	Average Soil Concentration to Achieve a Target Cancer Risk Level of: (mg/kg)								Soil Concentration to Achieve the CDI = AIC[a] (maximum plausible intake rates)		
	1 x 10^{-7}		1 x 10^{-6}		1 x 10^{-5}		1 x 10^{-4}				
	Cd	As	Cd	As	Cd	As	Cd	As	Mn	Cu	Zn
Current Recreational											
Ingestion											
Pond 2 Bottom Sediments		19		190							
Pond 2 Exposed Sediments		9.5		95							
Current Occupational											
Ingestion											
Pond 2 Exposed Sediments		1.7*[b]		17		170		1,700			
Inhalation											
All Exposed Sediments	5,600[c]	254[c]									
Current Downwind Residential											
Inhalation (all source areas)											
Warm Springs	88[c]	38[c]	880[d]	380[d]							
Eastside Residences	88[c]	38[c]	880[f]	380[f]							
Ingestion Through Inhalation											
Warm Springs		228*									
Eastside Residences		228*									
Potential Future Onsite Residential											
Ingestion											
Pond 1 Exposed Sediments		0.1*		1*		10		100	4,800[ef]	900[e]	5,000[e]
Inhalation											
All Sources Areas w/in the Ponds	88[c]	38[c]									

[a] Daily Intake = Acceptable Intake Chronic (mg/kg in soil)
[b] An asterisk (*) by the value indicates it is less than concentrations in other areas of the state (see Table 7 of the Technical Memorandum "Risk Based Potential Soil, Cleanup Levels").
[c] These two must be added together to obtain a 10^{-7} cancer risk.
[d] These two must be added together to obtain a 10^{-6} cancer risk.
[e] "Cleanup" concentration for a child (1 to 4 years old).
[f] Manganese "cleanup" concentration for an older child (5 to 11 years old) is 35,000 mg/l.

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cancer risks due to dust inhalation or ingestion range from zero to 9×10^{-6}. No potential human health threat was identified from exposure to noncarcinogenic contaminants for the current residential scenario.

Environmental Risks

Under current conditions, the average concentrations of several site inorganic contaminants in surface water exceed Montana standards for the protection of aquatic life. The chronic toxic effects of site contaminants may be expressed in local fish and wildlife populations through reduced growth rates, reduced fertility, and increased mortality. A principal environmental impact associated with the operable unit is the periodic fishkills in the Clark Fork River, which are believed to result from the solubilization of metal salts from tailings in the Mill-Willow Bypass during summer rainfall events. Current effects on other local wildlife populations are unknown.

Future adverse environmental effects without remediation are expected to be similar to current conditions. Periodic fishkills can be expected to recur and chronic contaminant effects (reduced growth, fertility, etc.) may be expressed in fish and/or wildlife populations. The potential also exists for a catastrophic event (flood, earthquake) where the pond system berms could be breached, releasing site contaminants that could adversely affect aquatic resources (fish and wildlife populations, aquatic habitat) for miles downstream.

PROBLEM DEFINITION
(Chapter 4)

SITE PROBLEMS

Eight environmental and human health concerns have been identified for which the feasibility study develops site objectives and remedial action alternatives. The eight problems are based on the results of the remedial investigations, applicable or relevant and appropriate requirements (ARARs), and the public health and environmental assessment. Chapter 4 describes each of the problems and discusses the relationship between the problems at the Warm Springs Ponds Operable Unit and those existing within the remainder of the Silver Bow Creek Site.

The eight human health and environmental problems are described in terms of four media: pond bottom sediments, surface water, tailings deposits and contaminated soils, and groundwater. The media are discussed below in terms of the problems identified with each.

Media 1--Pond Bottom Sediments

Pond Stability--Floods. Montana Department of Natural Resources and Conservation (DNRC) dam safety rules control the minimum level of flood protection for the design of dams within the State of Montana. The Warm Springs Ponds are classified as high hazard dams for which the dam safety rules require the ponds' outlet structures to pass the following fractions of a probable maximum flood (PMF): 0.2 PMF for Pond 1, 0.3 PMF for Pond 2, and 0.5 PMF for Pond 3. The

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pond berms, as currently constructed, would likely be damaged during these design floods. Hence, the pond system requires modification to meet the dam safety rules.

Pond Stability--Earthquakes. The Warm Springs Ponds are located within the northern section of the Intermountain Seismic Belt, which is a zone of major earthquake activity within the North American tectonic plate.[4] At least 230 earthquakes with magnitudes greater than 4.0 have occurred at epicenters within 187 miles of the Warm Springs-Butte area during the last 107 years of recorded earthquakes.[5]

The ground shaking during an earthquake can cause berms that are not adequately designed and constructed to flow like a liquid, slumping and releasing the water and semisolids behind them. Earthquakes can also cause sloshing of the water in a pond, creating waves that overflow or erode berms, causing berm failure. A review of the limited information available on the construction of the Warm Springs Ponds berms shows that they are not strong enough to withstand even a moderate earthquake.

The Montana dam safety rules require that if a dam is in a region subject to earthquakes, the dam must be designed to withstand the most severe earthquake that can be reasonably anticipated. This design earthquake is known as the maximum credible earthquake (MCE).

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[4] International Engineering Company (IECO), 1981. Geotechnical and Hydrologic Studies, Warm Springs Tailings Ponds, Anaconda, Montana. Prepared for Anaconda Copper Company, Denver, Colorado.

[5] Ibid.

A review of available information regarding the embankment materials confirms that the east-west and north-south berms are likely to fail in a moderate-to-severe earthquake; the likelihood of failure appears to be greater than previously reported. This was determined by a preliminary stability evaluation performed for this study, which indicated that the downstream slopes of the berms have potential to fail at accelerations from 0.05 to 0.07 g (g is the standard symbol for the acceleration of gravity). For comparison, in 1981, IECO determined that the acceleration at Warm Springs Ponds during a maximum credible earthquake could be as high as 0.23 g. These preliminary conclusions will have to be further investigated and confirmed during the remedial design phase.

Failure of the upstream slopes (faces) of the berms was not examined in this study because information on the materials and construction of the upstream slopes was not available. During the remedial design investigation, the potential for upstream slope failure also will have to be investigated.

Failure of the berms in an earthquake could result in at least partial release of the contents of the ponds. The sludges and tailings in the ponds are sufficiently liquid that they could migrate a considerable distance if released from the ponds. Although it has not been determined that the tailings in Warm Springs Ponds could also experience spontaneous liquefaction, this is a process that has been observed in seismically induced failures of other tailings ponds. If this process did occur, the tailings and sludges could flow for miles, contaminating a large area downstream of the ponds.

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Media 2--Surface Water

Fishkills in The Mill-Willow Bypass. There have been five documented fishkills associated with the Mill-Willow Bypass since 1983. They occurred on August 9, 1983; August 2, 1984; July 3, 1987; May 27, 1988; and July 13, 1989, and are documented in Montana Department of Fish, Wildlife, and Parks memoranda for these years. Data are not yet available on the previously mentioned fishkill that occurred in July 1989.

All five fishkills followed a similar pattern. They were associated with locally intense thunderstorms in the Warm Springs Ponds area, usually after extended dry periods. The fishkills started in the Mill-Willow Bypass and extended down the Clark Fork River for various distances. In the 1984 event, over a thousand dead fish were observed in a 15- to 20-mile stretch of the Clark Fork River. In July 1989, over 5,000 dead fish were reported. The fishkills have been linked to high concentrations of copper in the water; zinc concentrations and low pH levels may also be factors in fish mortality.

The available data indicate rapid elevation and dissipation of the metals concentrations during storm events, which implies that they are derived from a readily available source of highly soluble compounds, i.e., metal salts. A source of such salts has been identified along the Mill-Willow Bypass. During extended dry periods, salts of copper and zinc form by surface oxidation and/or the evaporation of soil moisture on the tailings deposits that exist along the bypass. There are approximately 21 acres of tailings deposits along the bypass. The copper salts are clearly visible on the

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tailings deposits during warmer months as green- and blue-colored surface deposits.

The postulated mechanism for the fishkills is that the rain water dissolves the metal salts and washes them into the by-pass, resulting in metal concentrations high enough to cause mortality. Elevated levels of metals detected in the gills of dead fish suggest that the fish died from acute exposure to metal contaminants.

While transient phenomena such as the observed fishkills are difficult to study and even more difficult to model, the evidence available at this time points to the visible salts on the tailings deposits as the primary cause of the fishkills.

Metal Loads in the Stream Flows. Silver Bow Creek, Mill Creek, and Willow Creek are all contaminated with detectable levels of heavy metals, mostly copper, arsenic, lead, and zinc. (Tables 2-8 through 2-11 in Chapter 2 summarize the surface water quality at the site, including all of the metals detected.) For example, in the Phase I remedial investigation, on the average, the inflow to the ponds, the discharge from Pond 2, and the combined flows of Mill and Willow Creeks exceeded Montana's chronic water quality standard for copper during the Phase I remedial investigation. The standard was exceeded in 100, 70, and 60 percent of the samples for those three sampling points, respectively.

The Mill-Willow Bypass was constructed to route the comparatively cleaner Mill and Willow Creek flows around the ponds and to the Clark Fork River without mixing with the comparatively more contaminated Silver Bow Creek flow. However, recent data indicate that, although Mill and Willow

Creeks are cleaner than Silver Bow Creek, they still contribute a portion of the total amount of metals reaching the operable unit (arsenic--34 percent, copper--6 percent, cadmium--3 percent, lead--3 percent, zinc--4 percent).

The pond system treats the Silver Bow Creek flow by two processes: 1) settling out suspended solids, such as tailings, and 2) precipitating dissolved metals. Thus, metal contaminants, whether suspended or dissolved, are removed to some degree by the pond system.

Physical settling of suspended solids occurs simply because the flow velocities in the ponds are very low compared to the velocities in the creek channel. The removal of dissolved metals occurs in part because of photosynthetically-induced chemical precipitation, and uptake of metals by and subsequent settling of biota and aquatic plants. The effectiveness of the ponds is enhanced by the addition of lime to precipitate metals during colder months when the amount of light available for photosynthesis and biological activity is diminished.

Without the treatment in the pond system, the Montana chronic water quality standards for the protection of aquatic life would be regularly exceeded just upstream of the beginning of the Clark Fork River. For example, available information indicates the standard for copper (12 ug/l for a calcium carbonate hardness of 100 mg/l), would be exceeded more than 75 percent of the time. Even though the pond system currently treats the Silver Bow Creek flow (Mill and Willow Creeks receive no treatment), the water quality standards for several contaminants are still frequently exceeded. The dissolved metals in the three creeks ultimately contribute to the chronic exposure of downstream fish.

Tailings in the Mill-Willow Bypass. The total amount of identifiable surficial tailings in the bypass has been estimated at 79,000 cubic yards. This includes 76,000 cubic yards of exposed tailings deposits and 3,000 cubic yards of tailings with vegetation cover.

These tailings can be eroded and transported out of the bypass to the Clark Fork River with higher flow events such as bank-full conditions transporting larger volumes of sediments. Once deposited in and along the banks of the Clark Fork River, they contribute to the contamination that already exists there and thus can contribute to adverse effects to fish.

Transport of Upstream Tailings to the Clark Fork River. The Warm Springs Ponds are 27 river miles from Butte, where most of the mining-related activities occurred that led to the contamination. Silver Bow Creek is contaminated along much of those 27 miles, with several large deposits of tailings interspersed with many smaller deposits (See Figure ES-3). There are also much smaller deposits of tailings along Mill and Willow Creeks.

Altogether, some 3 million cubic yards of streamside tailings can be estimated to exist upstream of the Warm Springs Ponds.[6] These tailings are eroded by the flows in the creeks; high flows especially can erode and move large quantities of these tailings. A recent flood study estimated that a 100-year flood on Silver Bow Creek would

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6 Hydrometrics, 1983. Summit and Deer Lodge Valleys Long-Term Environmental Rehabilitation Study, Butte-Anaconda, Montana, Volume VII, Warm Springs Ponds. Prepared for the Anaconda Minerals Company, Butte, Montana.

deliver 100,000 cubic yards (one football field 47 feet deep) of sediments to the Warm Springs Ponds.[7] These sediments would consist of both natural sediments and tailings. Because they could be carried by high flows that could not be routed through the ponds, the majority of the eroded tailings could be routed around the pond system and carried by the rapid flow through the area to the Clark Fork River.

Small scale movements of tailings in Silver Bow Creek (less than 2-year storm events) are primarily settled out in the pond system. However, tailings moving down Mill and Willow Creeks currently flow past the pond system into the Mill-Willow Bypass and on into the Clark Fork River. Calculations indicate that without modification Pond 3 can accept flows up to 600 cfs without causing scour of sediments near the discharge structures. Scouring could result in higher concentrations of metals leaving Pond 3 than entering it. Such scouring is likely in Pond 2 at even lower flow rates due to its very shallow depth and much lower effective volume.

A flow of 600 cfs equates to about a 2-year storm. Thus, any floods above a 2-year storm have to be routed around the pond system. Because of this, much of the 3 million cubic yards of tailings upstream of the Warm Springs Ponds can be expected eventually to reach the Clark Fork River as they are eroded by high flow events. The transport of these tailings to the Clark Fork River will contribute to the tailings contamination that already exists in the river.

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[7] CH2M HILL, 1988. Silver Bow Creek Flood Modeling Study. Prepared for State of Montana Department of Health and Environmental Sciences, Helena, Montana.

Media 3--Tailings Deposits and Contaminated Soils

Figure ES-1 shows the areas of tailings deposits around the pond system. In addition to these areas, there are soils that contain varying percentages of tailings or that are otherwise metal contaminated and areas of pond bottom sediments that were historically submerged in Ponds 1 and 2, but which are now exposed. The total area of tailings deposits and contaminated soils, as described in Chapter 2, is estimated to be approximately 420 acres with a corresponding volume of 1.9 million cubic yards. (See Table ES-1.)

The primary pathways identified for potential human exposure to these contaminants are direct (skin) contact, inhalation of dust from the surface, and incidental ingestion of contaminated media (soil and sediment).

Media 4--Groundwater

Exceedances of primary maximum contaminant levels for cadmium and arsenic were detected in one well located within Pond 1 and in several wells downgradient of Pond 1. The affected wells downgradient of Pond 1 are completed in the shallow sand and gravel aquifer.

The known area of primary maximum contaminant level exceedances in groundwater caused by the pond system is in and below Pond 1 and is estimated to cover 180 acres (see Figure 2-18). There are likely two primary reasons why the area of contamination is not more extensive. Most significantly, the pond bottom sediments (tailings and sludges) form a low permeability layer on the bottoms of the ponds, particularly in Ponds 2 and 3. Thus, the contaminated water in the ponds and in the sediments does not leak out and contaminate the groundwater to the degree that it otherwise would. Additionally, upward gradients in

the aquifer north of Pond 1, and the interception of the groundwater in that area by the Clark Fork River, have kept the groundwater contamination in the area of the ponds from spreading very far north.

The exceedances of the primary maximum contaminant levels are addressed in this feasibility study.

INTERACTIONS BETWEEN HUMAN HEALTH AND ENVIRONMENTAL PROBLEMS

In addition to describing the eight human health and environmental problems, Chapter 4 also discusses the relationships between those problems and the remainder of the Silver Bow Creek Site upstream of the Warm Springs Ponds. The most significant point made is that the upstream areas are the source of the very large volume of contaminated water flowing into and through the operable unit. The ponds, while not currently capable of providing totally adequate treatment of the contaminated flows in Mill, Willow, and Silver Bow Creeks, are nonetheless an important treatment system. They provide significant protection of the Clark Fork River from the continuous flow of contamination coming from upstream areas.

The levels of contamination in Mill, Willow, and Silver Bow Creeks will likely be reduced by future cleanup actions taken upstream of the Warm Springs Ponds. But, until that time, the pond system will be needed to treat the flows and thereby improve the water quality in the three creeks. This is an important factor in determining the types of alternatives that can be developed for the Warm Springs Ponds Operable Unit. Alternatives that would eliminate or substantially alter the existing pond treatment would have

to include alternative treatment capacity for the contaminated surface water if an equivalent level of aquatic protection is desired.

IDENTIFYING REMEDIAL OBJECTIVES AND GENERAL RESPONSE ACTIONS
(Chapter 5)

REMEDIAL ACTION OBJECTIVES

Remedial action objectives are site cleanup goals, designed to address the site problems identified in Chapter 4. ARARs, when available and adequately protective, should form the basis of the site objectives. When ARARs are not available (as for human exposure to contaminated soil at the Warm Springs Ponds Operable Unit), then site-specific human health and environmental protectiveness standards, identified through the public health and environmental assessment process, form the basis of the remedial action objectives.

Based on the identified problems, the results of the Public Health and Environmental Assessment, and the analysis of ARARs, a list of remedial action objectives has been established for the Warm Springs Ponds Operable Unit. They are listed in Table ES-4.

GENERAL RESPONSE ACTIONS

Having identified remedial action objectives, the next step is to identify general response actions, or cleanup techniques, that could satisfy the remedial action objectives for each medium of interest.

Table ES-4
RELATIONSHIP OF SITE PROBLEMS TO REMEDIAL ACTION OBJECTIVES

Problems	Objectives
Pond Bottom Sediments	
Pond integrity--floods.	Prevent the release of the pond sediments from design floods and earthquakes
Pond integrity--earthquakes.	
Surface Water	
Fishkills	Meet ambient water quality standards for aquatic life at the identified compliance point
Metal loads in the flows of Mill, Willow, and Silver Bow Creeks	
	Prevent ingestion above maximum contaminant levels and established reference doses for copper, iron, zinc, and cadmium. Also prevent ingestion of water containing arsenic in concentrations that would cause an excess cancer risk greater than 10^{-4} to 10^{-7}
Erosion of tailings in the Mill-Willow Bypass into the Clark Fork River	Reduce the potential for tailings in the Mill-Willow Bypass to reach the Clark Fork River
Transport of tailings from upstream reaches of Silver Bow Creek to the Clark Fork River during floods and other high flow events	Reduce the potential for tailings in upstream areas of Silver Bow Creek to reach the Clark Fork River
Tailings Deposits and Contaminated Soils	
Human and environmental exposure to surface contamination	Reduce the potential for human exposure to exposed tailings and other surface contamination to satisfy acceptable intake criteria
Groundwater	
Contaminated groundwater in the Pond 1 area	Reduce the metals contamination in the groundwater downgradient of the ponds to achieve compliance with maximum contaminant levels

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For the seven remedial action objectives, Table ES-5 identifies the general response actions possible for the types of problems existing at Warm Springs Ponds.

AREAS AND VOLUMES OF CONTAMINATED MEDIA

Table ES-1 shows the total areas and volumes of contaminated media to which the general response actions might be applied.

IDENTIFYING A RANGE OF MEDIA-SPECIFIC ACTIONS
(Chapter 6)

REMEDIAL TECHNOLOGIES AND PROCESS OPTIONS

The building blocks for conducting site cleanup are the remedial technologies and process options. Remedial technologies are methods for handling specific site problems, and include such methods as chemical treatment, capping, dewatering, and excavation. Remedial technologies are more specific than the general response actions (e.g., containment, treatment, and removal) identified in Chapter 5. In turn, process options are more specific than remedial technologies and describe various processes within a particular remedial technology; for example, capping (a remedial technology) could be done by using a native soil cap or a clay cap (process options).

The feasibility study identifies an extensive list of remedial technologies and process options. The technologies and process options then are initially screened to eliminate those that are unrelated to the problems at the site or that are technically infeasible for use at the site.

Table ES-5

GENERAL RESPONSE ACTIONS FOR WARM SPRINGS PONDS

Objectives	Problems	General Response Actions[1]
MEDIA--Pond Bottom Sediments		
1. Prevent the release of pond bottom sediments from floods and earthquakes	Pond integrity--Floods can cause release of sediments	No action
		Raise the berms to keep them from being overtopped by a flood (Containment)[2]
		Armor the berms against high velocity flows (Containment)
		Construct or enlarge bypass channels (Containment)
		Construct spillways to pass flood flows out of ponds without berm damage (Containment)[3]
		Remove the contents of the ponds from the floodplain (Removal)
		Treat the contents of the ponds after removal to decrease toxicity (Treatment)
		Dispose of sediments, with or without previous treatment (Disposal)
		Solidify pond bottom sediments in place (Chemical Stabilization)
	Pond integrity--Earthquakes can cause release of sediments	No action
		Add rock or other fill material (weight) to the berms (Physical Stabilization)
		Remove the contents of the ponds from the floodplain (Removal)
		Treat the contents of the ponds after removal to decrease toxicity (Treatment)
		Dispose of sediments with or without previous treatment (Disposal)
		Solidify pond bottom sediments to reduce their earthquake susceptibility (Stabilization)

[1] The standard terminology for the general response actions is given in parentheses.

[2] The general response actions listed would upgrade the current containment of the tailings and sediments. Therefore, they are assigned the designation "Containment."

[3] This general response action assumes that the flood would be allowed to flow through the ponds. The preceding three general response actions assume that the flood would be diverted around the ponds.

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Table ES-5 (Continued)

Objectives	Problems	General Response Actions[1]
MEDIA--Surface Water		
2. Meet water quality standards for aquatic life at the identified compliance point	Fishkills	No action Isolate the tailings (the contaminant source) from the streamflow (Containment) Remove contaminants from the streambed (in this case, the Mill-Willow Bypass) (Removal) and treat or dispose of them in an appropriate way (Treatment or Disposal)
	Dissolved metals in the flows of Mill, Willow, and Silver Bow Creeks	No action Treat the streamflow (in this case, improve or replace the current treatment system) (Treatment)
3. Prevent ingestion of water within the operable unit above maximum contaminant levels and established reference doses for copper, iron, lead, zinc, and cadmium. Also prevent ingestion of water containing arsenic in concentrations that would cause an excess cancer risk greater than 10^{-4} to 10^{-7}.	Dissolved metals in the flows of Mill, Willow, and Silver Bow Creeks	No action Treat the streamflow (in this case, improve or replace the current treatment system) (Treatment)
4. Reduce the potential for tailings in the Mill-Willow Bypass to reach the Clark Fork River	Erosion of tailings in the Mill-Willow Bypass into the Clark Fork River	No action Cap or otherwise stabilize the surface against erosion (Containment) Remove the tailings from the bypass (Removal) and dispose of them in an appropriate way (Disposal) After removal, treat the tailings to reduce their toxicity or mobility. Treatment may be used prior to disposal (Treatment)
5. Reduce the potential for tailings in upstream areas of Silver Bow Creek to recontaminae the Mill Willow Bypass and reach the Clark Fork River[4]	Floods and other high flow events can cause transport of tailings from upstream reaches of Silver Bow Creek to the Clark Fork River	No action Provide a settling basin to reduce the flow rates and allow for settling (Containment) Filter the streamflow (Treatment)

[4]General response actions that would directly address the upstream tailings, such as removal or stabilization, are not considered in this feasibility study. Such alternatives will be evaluated in a separate feasibility study addressing the upstream areas.

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Table ES-5 (continued)

Objectives	Problems	General Response Actions[1]
MEDIA--Tailings Deposits and Contaminated Soils		
6. Reduce the potential for human exposure to exposed tailings and other surface contamination	Human and environmental exposure to surface contamination	No action Remove the surface contamination to reduce its toxicity or mobility (Treatment) Cap or otherwise isolate the surface contamination (Containment) Limit access to the site (Institutional Controls) Fencing (Institutional Controls)
MEDIA--Groundwater		
7. Reduce the metals contamination in the groundwater downgradient of the ponds to achieve compliance with maximum contaminant levels	Contaminated groundwater in the area below the Pond 1 berm	No action Remove contaminant sources causing the groundwater contamination (Removal) Stabilize the contaminant sources causing the groundwater contamination (Treatment) Cap or otherwise isolate the contaminant sources (Containment) Treat the contaminant sources (e.g., sediments in the area and exposed tailings) (Treatment) Pump to remove the contaminated groundwater (Removal) Treat the groundwater after removal (Treatment) Treat the groundwater in place (Treatment) Limit access to the groundwater (Institutional Controls)

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The feasibility study next includes a second evaluation and screening of process options for each remedial technology retained in the initial screening. In screening technologies and process options at this stage of the study, three criteria are used, the most important of which is the effectiveness of the process option at protecting public health and welfare and the environment. To a less significant degree, the process options are screened on the basis of their implementability and cost. Altogether, 59 remedial technologies and process options were retained for possible use in assembling media-specific actions. Chapter 6 and Appendix C contain comprehensive tables detailing the two-step screening process.

ASSEMBLING MEDIA-SPECIFIC ACTIONS

The study next assembles media-specific actions. Media-specific actions are assembled by combining selected remedial technologies and process options to achieve the individual remedial action objectives identified for the operable unit.

Twelve media-specific actions were initially assembled and they are listed in Table ES-6.

Most feasibility studies would not assemble media-specific actions at this point, but rather would proceed directly with assembling the technologies and process options into comprehensive alternatives. However, for sites such as the Warm Springs Ponds Operable Unit, at which interactions among media are not significant to the development of separate actions for the media, the assembly of comprehensive alternatives can be completed later in the feasibility study process. While there are some interactions between the media, those interactions do not significantly affect the

TABLE ES-6
DESCRIPTION OF THE MEDIA-SPECIFIC ACTIONS

MEDIA 1: POND BOTTOM SEDIMENTS

In order to prevent the release of pond bottom sediments during design floods and earthquakes, either the pond berms or the sediments must be stabilized

Media-Specific Action 1.

[1] Berm Protection/Raise Berms — Berm Protection/Armor Berms

The existing containment of the pond bottom sediments would be improved by increasing the height of the berms to avoid overtopping by flood waters and by covering the outer slopes with a protective layer of riprap or other material to reduce the potential for erosion of the berms by flood waters.

Media-Specific Action 2.

Pond Closure/Drain/Dewater — Solids Treatment/Soil Cement

The existing containment of the pond bottom sediments would be improved by reducing their potential for migration (i.e., mobility). This would be accomplished by stabilizing/solidifying the sediments in place. Once stabilized/solidified, the sediments would be less susceptible to migration from the action of floods and earthquakes, even if the pond berms were seriously damaged, because they would no longer be erodible by the flood waters or susceptible to flowing. All of the tailings deposits and contaminated soils (Media 3) in the operable unit would also be solidified in the ponds as a permanent disposal action.

Media-Specific Action 3.

Berm Stabilization/Flatten Berm Slopes

The existing containment of the pond bottom sediments would be improved by upgrading the berms to withstand, without serious damage, the destructive forces of a design earthquake. This would be accomplished by flattening the slopes of the berms (i.e., increasing the width of the berms at their base).

MEDIA 2: SURFACE WATER

In order to attain compliance with the water quality standards for aquatic life and public health and maximum contaminant levels, it will be necessary to reduce the potential for exceedances of both the acute and the chronic standards over both the short term and the long term.

Media-Specific Action 4.

Excavation/Sediments — Land Disposal/--

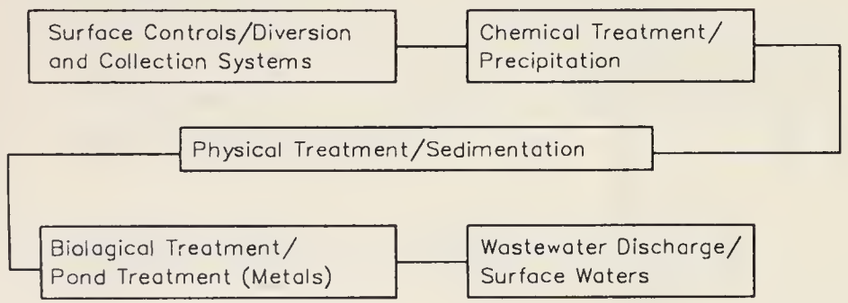
The potential for short-term exceedances of the acute water quality standards for aquatic life (such exceedances have been the cause of several fishkills) would be reduced by removing the exposed tailings and contaminated soil from the Mill Willow Bypass. This media-specific action would also help to reduce the potential for exceedances of the chronic and acute water quality standards for aquatic life and public health standards over the long-term in the Clark Fork River. The action would eliminate the potential for the exposed tailings currently in the bypass to be eroded by high flow events and transported to the Clark Fork River. The disposal process option would be determined by the process option(s) chosen for the exposed tailings and contaminated soils medium (see below).

[1] The format for listing technologies and process options is

Technology/Process Option

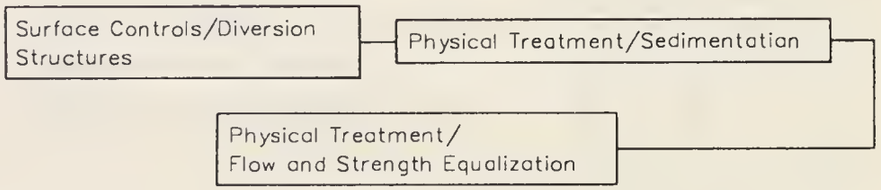
TABLE ES-6 (Continued)
DESCRIPTION OF THE MEDIA-SPECIFIC ACTIONS

Media-Specific Action 5.



To meet the chronic water quality standards for aquatic life in the Mill-Willow Bypass at the compliance point, treatment of the flows in Silver Bow Creek will have to be continued and improved. In addition, the flows in Mill and Willow Creeks will have to be treated. The continuing, improved treatment of contaminated creek flows would be provided by a pond treatment system: either a modified version of the existing system or a new treatment pond. As described in Chapters 2 and 7, the existing pond system treats the contaminated waters by a combination of chemical precipitation of dissolved metals, sedimentation of particulates, and a complex biological process that removes dissolved metals. A new pond system would use the same treatment process.

Media-Specific Action 6.

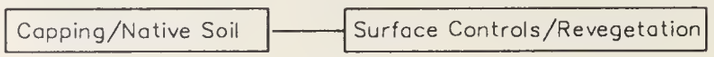


To provide for attainment of both the acute and chronic water quality standards for aquatic life over the long-term, both within the operable unit and in the Clark Fork River, it is necessary to reduce the potential for transport of suspended tailings and contaminated soils eroded from upstream areas. This could be accomplished either by reducing the potential for the tailings and contaminated soils to be eroded by floods, or by providing a settling basin upstream of the operable unit to trap the majority of the tailings and soil particles carried by flood waters. For the purposes of this feasibility study, the possibility of providing either a large flood impoundment or a smaller settling basin are explored (see Chapter 7). In addition to providing settling capacity, a new pond can provide flow equalization to allow metering flood waters into the pond treatment system for treatment to remove dissolved metal contaminants.

MEDIA 3: TAILINGS DEPOSITS AND CONTAMINATED SOIL

In order to reduce the human health and environmental threats associated with tailings deposits and contaminated soils, the potential for human and environmental exposure to the tailings and soils must be decreased.

Media-Specific Action 7.



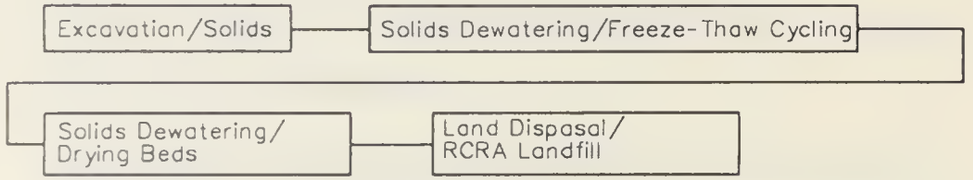
The potential for exposure to the tailings deposits and contaminated soils would be reduced by placing barriers over the areas of surface contamination. The barriers would be a layer of native soils vegetated with native species to protect the surface contamination from erosion or disturbance. The barriers would reduce the potential both for direct human contact with contaminants and for migration of the contaminants through the air pathway.

Media-Specific Action 8.

The potential for exposure to the tailings deposits and contaminated soils would be decreased by flooding contaminated areas with shallow water. This would reduce both the potential for direct human contact with the contaminants and for migration of the contaminants through the air pathway.

TABLE ES-6 (Continued)
DESCRIPTION OF THE MEDIA-SPECIFIC ACTIONS

Media-Specific Action 9.



The potential for exposure to the tailings deposits and contaminated soils would be decreased by removing the tailings and soils from the operable unit and disposing them in an existing, offsite, RCRA-permitted landfill.

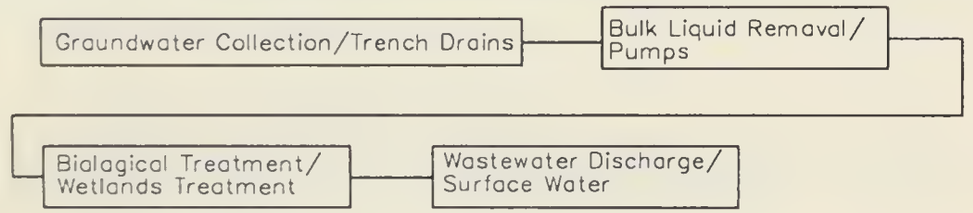
Media-Specific Action 10.

The potential for exposure to the tailings deposits and contaminated soils would be decreased by excavating the tailings and soils and disposing them onsite in a landfill for hazardous wastes. Disposal would be in Pond 1 either prior to solidification (Media-Specific Action 2) or prior to capping (Media-Specific Action 7).

MEDIA 4: GROUNDWATER

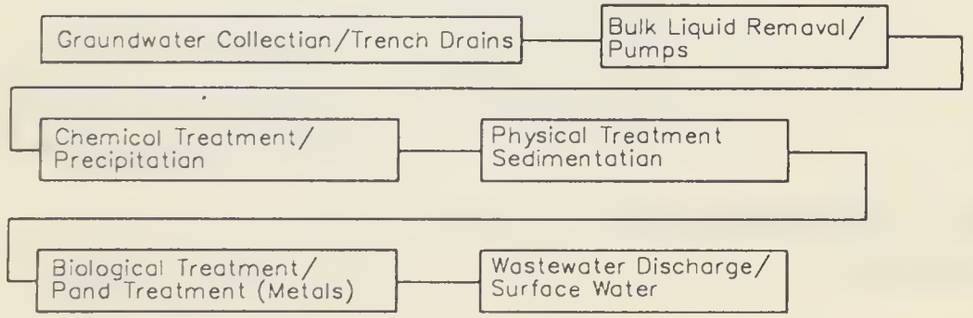
Media-Specific Action 11.

In order to achieve compliance with maximum contaminant levels, the groundwater must be removed and treated.



Attainment of maximum contaminant levels would be accomplished by collecting the groundwater in trenches, pumping it to the surface, and treating it in a wetland prior to discharging it to the Clark Fork River.

Media-Specific Action 12.



Attainment of maximum contaminant levels would be accomplished by collecting the groundwater in trenches, pumping it to the surface, and piping it to the inlet of the pond treatment system for treatment along with the surface waters.

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range of actions that can be developed for the problems identified at the operable unit. The known interactions between the media are discussed in Chapter 6.

RANGE OF THE MEDIA-SPECIFIC ACTIONS

There are certain features of the Warm Springs Ponds Operable Unit that tend to reduce the range of technologies that can be implemented. The continual flow of an average of approximately 100 cfs of contaminated surface water through the operable unit has been mentioned as one such limiting feature. The other most significant factor is the nature of the pond berms and the limited range of technologies available for stabilizing berms. Flattening the slopes of the berms to enable them to withstand earthquakes and raising and armoring the berms to protect them from flood damage are the commonly accepted methods for stabilizing berms against floods and earthquakes; there simply are not proven, cost-effective alternatives to be considered for stabilizing the berms.

Similarly for several of the other human health and environmental problems identified for this operable unit, one factor or another limits the range of approaches that are feasible. Only for the tailings deposits and contaminated soils is there a wide range of approaches that might be taken. Chapter 6 discusses all the limiting factors, media by media.

DEVELOPMENT OF THE MEDIA-SPECIFIC ACTIONS
(Chapter 7)

As can be seen by reviewing Table ES-6, the media-specific actions assembled in Chapter 6 are basically concepts. For each, there are numerous ways in which they could be implemented. In fact, in Chapter 7 more than one approach is developed for two of the media-specific actions.

In order to evaluate the effectiveness, cost, and other aspects of the media-specific actions in Chapter 8, more clearly defined examples of those actions must be developed. In Chapter 7, conceptual designs are developed for the media-specific actions, detailing one or more specific approaches that could be used to implement each. It is these specific approaches that are assembled into alternatives in Chapter 8. Table ES-7 lists the 16 media-specific actions (including options) developed in Chapter 7.

ASSEMBLY AND ANALYSIS OF ALTERNATIVES
(Chapter 8)

In Chapter 8, six comprehensive remedial action alternatives are assembled by combining one or more media-specific actions for each of the affected media into an overall remediation package. The action alternatives are assembled from the 16 media-specific actions developed in Chapter 7. In addition, a "no-action" alternative is added to the range of alternatives and evaluated with the action alternatives as required by the NCP. The alternatives present a range of possible combinations. They are analyzed, both individually and comparatively, against seven of the nine evaluation criteria established by USEPA.

Table ES-7
MEDIA-SPECIFIC ACTIONS DEVELOPED
FOR THE WARM SPRINGS PONDS OPERABLE UNIT
FEASIBILITY STUDY

POND BOTTOM SEDIMENTS

1A. Stabilize pond berms to withstand a probable maximum flood (PMF)

1B. Stabilize pond berms to withstand fractions of a PMF (Pond 3, a 0.5 PMF; Pond 2, a 0.3 PMF; Pond 1, a 0.2 PMF)

2. Solidify pond bottom sediments

3. Stabilize pond berms to withstand a maximum credible earthquake

SURFACE WATER

4. Remove exposed tailings and contaminated soils from along the bypass

5A. Comprehensive upgrade of the current Pond 3 system

5B. Partial upgrade of the current Pond 3 system: replace the fuse plug, improve the trashrack, and improve the lime addition system

5C. Construct a new treatment pond

6A. Construct an 8,000-acre-foot upstream flood impoundment

6B. Construct 2,000-acre-foot upstream settling basin

TAILINGS DEPOSITS AND CONTAMINATED SOILS

7. Cap and revegetate all applicable areas

8. Flood all applicable areas

9. Excavate from all applicable areas; disposal in an offsite RCRA facility

10. Excavate from all applicable areas; disposal in an onsite waste repository (Pond 1) either prior to solidification (Media-Specific Action 2) or capping (Media-Specific Action 7)

GROUNDWATER

11. Install trench drain below Pond 1; treat groundwater in onsite wetlands

12. Install trench drains in and below Pond 1; treat groundwater in Pond 3.

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ASSEMBLY OF ALTERNATIVES

The seven alternatives considered for evaluation are presented in Table ES-8. Table ES-9 lists the alternatives approximately in order of decreasing overall attainment of ARAR goals and describes the specific actions that each includes.

Alternative 1 includes in situ solidification of all presently existing pond bottom sediments and all tailings deposits and contaminated soils excavated from areas within the operable unit. In situ solidification is an innovative treatment process that has not been extensively used for remediations of hazardous materials. It has been included as an alternative that relies on treatment of wastes to reduce their mobility, as required by CERCLA [121(b)(1)]. Flood and earthquake protection of the pond berms is not envisioned as necessary for the ponds because the sediments they contain would not, once solidified, be susceptible to release in the event of a berm failure. Because the three existing ponds would be rendered unusable as a result of solidification, Alternative 1 also includes the construction of a new treatment pond to continue the treatment of contaminated surface water currently provided by the existing ponds. An upstream flood impoundment to settle tailings out of flood flows and allow treatment of flood volumes (up to a 100-year flood) is also part of this alternative.

Alternative 2 protects all three of the existing ponds against both a maximum credible earthquake (MCE) and a probable maximum flood (PMF). It also includes an overall upgrading of the existing pond treatment system to improve both its reliability and its effectiveness, and the construction of an upstream flood impoundment.

Table ES-8

MEDIA-SPECIFIC ACTIONS FOR EACH ASSEMBLED ALTERNATIVE

MEDIA-SPECIFIC ACTION		DESCRIPTION	ALTERNATIVE 1	ALTERNATIVE 2	ALTERNATIVE 3	ALTERNATIVE 4	ALTERNATIVE 5	ALTERNATIVE 6	ALTERNATIVE 7 (no action)
POND BOTTOM SEDIMENTS	1A	Stabilize pond berms to withstand a probable maximum flood.		●					
	1B	Stabilize pond berms to withstand flood flows less than the probable maximum flood.			●	●	●	●	
	2	Stabilize/solidify pond sediments.	●						
	3	Stabilize pond berms to withstand a maximum credible earthquake.		◎	◎	◎	◎	◎	
SURFACE WATER	4	Remove and dispose of contaminated surface soils along the Mill-Willow Bypass.	●	●	●	●	◎	◎	
	5A	Overall upgrade of pond treatment system.		●	●	●			
	5B	Less comprehensive upgrade of pond treatment system.					◎	◎	
	5C	Construct a new treatment pond for continued water treatment.	◎						
	6A	Construct an upstream flood impoundment.	◎	◎					
	6B	Construct an upstream settling basin.			◎	◎	◎		
TAILINGS DEPOSITS AND CONTAMINATED SOILS[1]	7	Cap and revegetate exposed tailings and contaminated soils where feasible.				◐	◐		
	8	Flood exposed tailings and contaminated soils where feasible.						◐	
	9	Excavate exposed tailings and contaminated soils from appropriate areas; disposal at an offsite, RCRA facility.		◐					
	10	Excavate exposed tailings and contaminated soils from appropriate areas; disposal at an onsite, RCRA-equivalent facility (Pond 1) either prior to solidification (Media-Specific Action 2) or prior to capping (Media-Specific Action 7).	◎		◎				
GROUNDWATER	11	Groundwater collection below Pond 1 with wetland treatment.				◐	◐		
	12	Groundwater collection in and below Pond 1 with treatment in pond system.	●	●	●	●			

[1] Only the primary Media-Specific Action(s) for each alternative are shown for Tailings Deposits and Contaminated Soils. Because of conditions inherent in the various areas, more than one action is typically required for remediation of the tailings and soils.

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Table ES-9
ASSEMBLED ALTERNATIVES FOR WARM SPRINGS PONDS OPERABLE UNIT FEASIBILITY STUDY

MEDIA:	Pond Bottom Sediments		Surface Water				Groundwater	Soil
Alt.	Sediments Floods	Sediments Earthquakes	Fishkills	Dissolved Metals	Erosion of Tailings	Transport of Upstream Tailings	Contaminated Groundwater	Tailings Deposits and Contaminated Soils
1	Cease current operation of the pond system and solidify sludges and sediments in all three ponds.	Cease current operation of the pond system and solidify sludges and sediments in all three ponds.	Remove tailings deposits and contaminated soils from bypass; dispose of in Pond 1, 2, or 3 and solidify.	Construct a new, more effective treatment pond.	Remove tailings deposits and contaminated soils from the bypass; dispose of in Pond 1, 2 or 3, and solidify.	Construct an upstream flood impoundment of 8,000 acre-feet.	Install trench drains in and below Pond 1. Pump to new treatment pond inlet for treatment.	Excavate all material above the action level;[a] disposal in Pond 2 or 3 prior to solidifying the ponds.
2	Protect ponds against a PMF.	Protect ponds against an MCE.	Remove tailings deposits and contaminated soils from the bypass; dispose of in an offsite TSDF.	Comprehensive upgrade of the Pond 3 treatment system.	Remove tailings deposits and contaminated soils from the bypass; dispose of in an offsite TSDF.	Construct an upstream flood impoundment of 8,000 acre-feet.	Install trench drains in and below Pond 1. Pump to Pond 3 inlet for treatment.	Excavate all exposed areas above the action level;[a] offsite disposal; cap and revegetate Pond 1 and flood Pond 2.
3	Protect ponds against fractions of a PMF.[b]	Protect ponds against an MCE.	Remove tailings deposits and contaminated soils from the bypass; dispose of in Pond 1 prior to capping.	Comprehensive upgrade of the Pond 3 treatment system.	Remove tailings deposits and contaminated soils from the bypass; dispose of in Pond 1 prior to capping.	Construct an upstream settling basin of 2,000 acre-feet.	Install trench drains in and below Pond 1. Pump to Pond 3 inlet for treatment.	Excavate all exposed areas above the action level;[a] disposal in Pond 1; cap and revegetate Pond 1. Flood Pond 2.
4	Protect ponds against fractions of a PMF.[b]	Protect ponds against an MCE.	Remove tailings deposits and contaminated soils from the bypass; dispose of in Pond 1 prior to capping.	Comprehensive upgrade of the Pond 3 treatment system.	Remove tailings deposits and contaminated soils from the bypass; dispose of in Pond 1 prior to capping.	Construct an upstream settling basin of 2,000 acre-feet.	Install trench drains in and below Pond 1. Pump to Pond 3 inlet for treatment.	Cap and revegetate all material above the action level. Excavate tailings deposits and contaminated soils in bypass; dispose in Pond 1 prior to capping. Flood Pond 2.
5	Protect ponds against fractions of a PMF.[b]	Protect ponds against an MCE.	Remove tailings deposits and contaminated soils from the bypass; dispose of in Pond 1 prior to capping.	Partial upgrade of the treatment system: replace fuse plug; improve trashrack and lime addition.	Remove tailings deposits and contaminated soils from the bypass; dispose of in Pond 1 prior to capping.	Construct an upstream settling basin of 2,000 acre-feet.	Install trench drains below Pond 1; treat in onsite wetlands.	Cap and revegetate all exposed areas above the action level. Excavate tailings deposits and contaminated soils in bypass; dispose in Pond 1 prior to capping. Flood Pond 2.

Table ES-9
(continued)

MEDIA:	Pond Bottom Sediments		Surface Water				Groundwater	Soil
Alt.	Sediments Floods	Sediments Earthquakes	Fishkills	Dissolved Metals	Erosion of Tailings	Transport of Upstream Tailings	Contaminated Groundwater	Tailings Deposits and Contaminated Soils
6	Protect ponds against fractions of a PMF.[b]	Protect ponds against an MCE.	Remove tailings deposits and contaminated soils from the bypass; dispose of in Pond 1 prior to capping.	Partial upgrade of the treatment system: replace fuse plug; improve trashrack and lime addition.	Remove tailings deposits and contaminated soils from the bypass; dispose of in Pond 1 prior to capping.	No action.	Install trench drains below Pond 1; treat in onsite wetlands.	Flood all applicable areas;[a] excavate tailings deposits and contaminated soils in bypass and dispose in Pond 1; cap and revegetate Pond 1.
7	No action.	No action.	No action.	No action.	No action.	No action.	No action.	No action.

[a]All areas containing contaminated soils and tailings for which the specified technology is appropriate or applicable. For example, excavation is appropriate above Pond 3, below Pond 1, and along the bypass; it is not applicable for the tailings in Ponds 1 and 2. Preliminary action levels are 250 ppm for arsenic and 750 ppm for lead.
[b]Alternative would protect Pond 3 to a 0.5 PMF, Pond 2 to a 0.3 PMF, and Pond 1 to 0.2 PMF.
PMF = probable maximum flood
MCE = maximum credible earthquake

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Alternatives 3 through 6 all provide berm protection for each of the ponds against a full MCE and fractions of a PMF (0.2, 0.3, and 0.5 for individual ponds) as required by the Montana dam safety rules. They differ in the level of improvement to the pond treatment system and the use of a smaller upstream settling basin, instead of a flood impoundment, for tailings control.

Each of the first six alternatives also includes an excavation and disposal or containment option for the tailings deposits and contaminated soil, and one of the two groundwater remediation options developed in Chapter 7.

Alternative 7 is the no-action alternative required under CERCLA and is included as a baseline against which the other alternatives are evaluated.

DETAILED ANALYSIS OF ALTERNATIVES

As the final step in the feasibility study process, the seven remedial alternatives are analyzed to determine whether they satisfy specific statutory, regulatory, and other criteria. The analysis is conducted by evaluating the seven alternatives, first individually and then comparatively, against seven evaluation criteria prescribed by the USEPA. Two additional criteria, support agency acceptance and community acceptance, will be evaluated following the public comment period. Table ES-10 provides a listing of the first seven USEPA criteria and summarizes specific factors that further refine the criteria as they are to be used in the detailed analysis of the alternatives.

The evaluations in this study apply to the media-specific actions developed in Chapter 7. The development of the media-specific actions (and, therefore, the alternatives as well) at this stage is at a conceptual design, not a full design, level. Design details and cost estimates will continue to be refined

Table ES-10
CRITERIA FOR DETAILED ANALYSIS OF ALTERNATIVES

Protection of Human Health and the Environment	Compliance With ARARs	Long-Term Effectiveness	Reduction of Toxicity, Mobility, and Volume	Short-Term Effectiveness	Implementability	Cost	Support Agency Acceptance	Community Acceptance
How alternative provides human health and environmental protection	Compliance with contaminant-specific ARARs Compliance with action-specific ARARs Compliance with location-specific ARARs Compliance with other criteria, advisories, and guidance	Magnitude of residual risk Adequacy of controls Reliability of controls	Treatment processes used and materials treated Amount of hazardous materials destroyed or treated Degree of expected reductions in toxicity, mobility, and volume Degree to which treatment is irreversible Type and quantity of residuals remaining after treatment	Protection of community during remedial actions Protection of workers during remedial actions Environmental impacts Time until remedial action objectives are achieved	Ability to construct and operate the technology Reliability of the technology Ease of undertaking additional remedial actions, if necessary Ability to monitor effectiveness of remedy Ability to obtain approvals from other agencies Coordination with other agencies Availability of offsite treatment, storage, and disposal services and capacity Availability of necessary equipment and specialists Timing of new technology under consideration	Capital costs Operating and maintenance costs Present worth costs	Support agency dependent	Community dependent

following selection of an alternative and ultimately up until final implementation of it.

INDIVIDUAL ANALYSES OF ALTERNATIVES

Table ES-11 summarizes the results of the individual analyses of the alternatives against the seven USEPA criteria.

COMPARATIVE ANALYSIS OF ALTERNATIVES

Chapter 8 also presents a comparative analysis of the alternatives for each of the seven evaluation criteria. The purpose of this analysis is to identify the advantages and disadvantages of each alternative relative to the other alternatives. A summary of the comparative analysis is presented in Table ES-12. Compliance with federal and state ARARs is presented in Table ES-13. Costs are summarized in Table ES-14.

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Table ES-11
SUMMARY OF INDIVIDUAL ANALYSIS OF ALTERNATIVES

Criteria	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6	Alternative 7
Description	Solidify pond sediments; remove soils from bypass; construct a new treatment pond and a flood impoundment of 8,000 acre-feet; excavste contaminated soil with pond disposal and solidification; groundwater collection with treatment in new pond.	Stabilize pond berms against PMF and MCE; remove soils from bypass; upgrade treatment system; add flood impoundment of 8,000 acre-feet; excavate contaminated soil with offsite disposal; groundwater collection with treatment in Pond 3.	Stabilize pond berms against a partial PMF and the MCE; remove soils from bypass; upgrade treatment system; add settling basin of 2,000 acre-feet; excavate contaminated soil with Pond 1 disposal; cap Pond 1; groundwater collection with treatment in Pond 3.	Stabilize pond berms against a partial PMF and the MCE; remove soils from bypass; upgrade treatment system; add settling basin of 2,000 acre-feet; cap and revegetate contaminated soil; groundwster collection with treatment in Pond 3. Flood Pond 2.	Stabilize pond berms against a partial PMF and the MCE; remove soils from bypass; modify treatment system; add settling basin of 2,000 acre-feet; cap and revegetate contaminated soils; groundwater collection with wetlands treatment.	Stabilize pond berms against a partial PMF and the MCE; remove soils from bypass; modify treatment system; flood contaminated soils and cap Pond 1; groundwater collection with wetlands treatment.	No action.
Overall Protectiveness							
Pond Bottom Sediments	Risks reduced through solidification of sludges and sediments.	Risks reduced through stsbilization of pond berm against threat of failure.	Risks reduced through stabilization of pond berms against moderate cases.	Same as Alternative 3.	Same as Alternative 3.	Same as Alternative 3.	No reduction in risk; threat of pond failure increases with time.
Surface Water	New treatment pond and flood impoundment pond would provide improved water quality through enhanced treatment for all flows.	Upgraded treatment and flood impoundment pond would provide improved water quality through enhanced treatment for all flows.	Upgraded treatment pond and new settling pond would provide improved water quality. All flows less than 600 cfs and the first 2,000 acre-feet of flows greater than 600 cfs treated for suspended and dissolved metals. Remaining flows treated for suspended solids only.	Same as Alternative 3.	Modified treatment system and new settling pond would provide improved water quality for up to 210 cfs and the first 2,000 scre-feet of flows greater than 210 cfs. Flows above 120 cfs treated for suspended solids only.	Modified treatment system would provide improved water quality for up to 210 cfs. Only flows less than 210 cfs receive treatment.	No improvement in water quality. Frequent violations and periodic fishkills.
Tailings Deposits and Contaminated Soils	Risks reduced through excavation and solidification.	Risks reduced through excavation and offsite disposal at a RCRA TSDF. No treatment prior to disposal.	Risks reduced through excavstion and disposal under a RCRA-equivalent cap. No treatment prior to disposal.	Risks reduced through cspping in plsce and excavation with onsite disposal under a cap. Inherent risk of capping material in a flood plain exists below Pond 1. No treatment prior to capping.	Same ss Alternative 4.	Some reduction in risks through flooding in place and excavation with onsite disposal under a cap. No treatment prior to flooding or capping.	No reduction in risk of migration or exposure.

Table ES-11 (continued)

Criteria	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6	Alternative 7
Groundwater	Collection with treatment in a new treatment pond reduces risk of exposure and migration.	Collection with treatment in Pond 3 reduces risk of exposure and migration.	Same as Alternative 2.	Same as Alternative 2.	Collection with onsite wetlands treatment reduces risk of exposure and migration in groundwater, but increases risk of contamination of wetlands biota, sediment, and soils.	Same as Alternative 5.	No reduction in risk of migration or exposure.
Compliance with ARARs							
Chemical-specific, Location-specific, and Action-specific	See Table 8-4.	See Table 8-4.	See Table 8-4.	See Table 8-4.	See Table 8-4.	See Table 8-4.	See Table 8-4.
Long-Term Effectiveness and Performance							
Residual Risk	All present risks reduced; residual risks result from deposition of tailings and sludges in the new treatment and flood impoundment ponds.	All present risks addressed; residual risks result from unsolidified sludges in Ponds 1 and 2, and the continued deposition of tailings and sludges in the flood impoundment and Pond 3.	All present risks addressed; residual risks result from extreme floods, unsolidified sludges in Pond 2, capped sludges in Pond 1, the continued deposition of tailings and sludges in the settling basin and in Pond 3, and the discharge without dissolved metals treatment of flows greater than 600 cfs and 2,000 acre-feet.	All present risks addressed, residual risks result from extreme floods, unsolidified sludges in Pond 2, capped sludges in Pond 1, the continued deposition of tailings and sludges in the settling basin and in Pond 3, large quantity of capped material around the site, and the discharge without dissolved metals treatment of flows greater than 600 cfs and 2,000 acre-feet.	All present risks addressed; residual risks result from extreme floods, unsolidified sludges, continued use of Pond 2 during high flows, continued deposition of tailings and sludges in Pond 3 and tailings in the settling pond, large quantity of capped material around the site, and the discharge without dissolved metals treatment of flows greater than 210 cfs and 2,000 acre-feet.	Majority of present risks addressed; residual risks result from lack of treatment for flows greater than 210 cfs, threat of extreme floods, unsolidified sludges, continued use of Pond 2, continued deposition of tailings and sludges in Pond 3, and lack of containment on flooded soils and tailings.	All present risks remain unmitigated.

Table ES-11 (continued)

Criteria	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6	Alternative 7
Adequacy and Reliability of Controls	In situ solidification of sludges is unproven and because of sludge volume, solidification could take up to 14 years. Remaining controls are adequate to manage risks and are reliable with proper design, construction, operation, and maintenance.	All controls adequate and reliable for stated purpose. O&M required to maintain reliability.	All controls adequate and reliable for stated purpose. O&M required to maintain reliability.	Same as Alternative 3.	Wetlands treatment of extracted groundwater is an innovative, underdeveloped process. The adequacy and reliability of wetlands treatment cannot be stated with certainty. Other controls are adequate and reliable for their stated purpose. O&M required to maintain reliability. Modifications to pond treatment system may not be adequate to consistently achieve discharge standards.	Same as Alternative 5.	Inadequate to achieve remedial action objectives for the operable unit.
Reduction of Toxicity, Mobility, and Volume	Solidification of sludges directly reduces mobility of pond bottoms. New treatment ponds reduce toxicity of surface water. Excavation and solidification of soils and tailings reduces mobility. Groundwater collection and treatment reduces mobility and toxicity.	Stabilization of pond berms reduces mobility of pond bottoms for all cases. Upgraded treatment system and flood impoundment reduce toxicity of surface water. Excavation and offsite disposal of soils and tailings reduces their mobility. Groundwater collection and treatment reduces toxicity.	Stabilization of pond berms reduces mobility of pond bottoms for all but extreme cases. Upgraded treatment system and settling basin reduce toxicity of surface water. Excavation and onsite disposal of tailings reduces their mobility. Groundwater collection and treatment reduces mobility and toxicity.	Stabilization of pond berms reduces mobility of pond bottoms for all but extreme cases. Upgraded treatment system and settling basin reduce toxicity of surface water. Groundwater collection and treatment reduces mobility and toxicity. Capping tailings in place will reduce their mobility except in cases of extreme mobility.	Stabilization of pond berms reduces mobility of pond bottoms for all but extreme cases. Modified treatment system and settling basin reduces toxicity of surface water. Capping tailings in place will reduce their mobility. Groundwater collection and treatment in wetlands reduces mobility and toxicity of groundwater, but increases toxicity of wetland biota, sediment, and soils and may result in recontamination of groundwater.	Stabilization of pond berms reduces mobility of pond bottoms for all but extreme cases. Modified treatment system reduces toxicity of surface water. Flooding tailings in place will reduce their direct mobility. Groundwater collection and treatment in wetlands reduces toxicity of groundwater, but increases toxicity of wetland biota, sediment, and soils.	No reduction of toxicity, mobility, or volume.

Table ES-11 (continued)

Criteria	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6	Alternative 7
Short-Term Effectiveness							
Protectiveness	No increased risk to community during remediation. Protection of workers against dermal contact and inhalation of tailings dust required in tailings contaminated areas.	Same as Alternative 1.	Same as Alternative 1.	Same as Alternative 1.	Same as Alternative 1.	Same as Alternative 1.	Threat of pond failure increases with time. Other risks remain unchanged.
Environmental Impacts	Significant habitat alteration due to pond solidification and construction of new ponds. 1,200 acres of wetlands and open water habitat destroyed. Up to 600 acres of open water habitat created by new treatment pond. Potential for airborne release of tailings during implementation. Upstream flood impoundment will permanently alter up to 1,000 acres of rangeland. Planning required to prevent affecting a pair of bald eagles sighted within the operable unit. Solidification would remove 1,000 acres of eagle feeding area.	Some temporary habitat alteration will occur during remediation. Only the upstream flood impoundment and capping Pond 1 will permanently alter up to 1,000 acres of rangeland. Potential for airborne release of tailings during implementation. Treatment of bypass flows in the pond system will dry up a portion of the bypass during all flows less than a 100-year flood (up to 4,000 cfs, eliminating an established catch and release fishery. Planning required to prevent affecting a pair of bald eagles sighted within the operable unit.	Same as Alternative 2, except upstream settling basin will alter significantly less rangeland (500 acres vs. 1,000 acres) than the flood impoundment. Planning required to prevent affecting a pair of bald eagles sighted within the operable unit.	Some temporary habitat alternation will occur during remediation. Upstream settling basin will permanently alter up to 500 acres of rangeland. Potential for airborne release of tailings during implementation. Treatment of bypass flows in the pond system will dry up s portion of the bypass during all flows less than 600 cfs, eliminating an established fishery. Planning required to prevent affecting a pair of bald eagles sighted within the operable unit.	Same as Alternative 4, except the bypass will only be affected during flows of less than 210 cfs or above 210 cfs but under 2,000 acre-feet. Planning required to prevent affecting a pair of bald eagles sighted within the operable unit.	Same as Alternative 5, except there would be no impact on rangeland due to no upstream settling basin. Planning required to prevent affecting a pair of bald eagles sighted within the operable unit.	Continued impacts from existing conditions.
Time Until Completion	Approximately 1/ years	Three to four construction seasons.	Two to three construction seasons.	Same as Alternative 3.	Two to three construction seasons to complete. Startup of wetlands system may take 5 years.	Same as Alternative 5.	Not applicable.

Table ES-11 (continued)

Criteria	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6	Alternative 7
Implementation, Reliability, Constructibility							
Ability to construct and operate	In situ solidification process is an innovative technology with no past remediation experience. The effectiveness of the process for remediation is unknown. It has been used in Japan for swamp stabilization. Other components are feasible, implementable, and reliable for their stated objective. Land acquisition for the flood impoundment may prove difficult.	All components are feasible, implementable, and reliable for their stated objective. Availability of adequate riprap is unknown. Land acquisition for the flood impoundment may prove difficult.	Same as Alternative 2, except land acquisition for settling basin may prove less difficult than for the flood impoundment.	Same as Alternative 3.	Wetlands treatment system is an innovative technology. It has been used with varying degrees of success. May require extensive startup time. Long-term reliability cannot be fully assessed. All other components are feasible for their stated objective. Availability of adequate riprap is unknown. Land acquisition for the settling basin may prove difficult.	Same as Alternative 5, except there is no land acquisition required.	Not applicable.
Permits Required	MPDES permit required for pond discharge.	Same as Alternative 1.	Same as Alternative 1.	Same as Alternative 1.	Same as Alternative 1.	Same as Alternative 1.	Same as Alternative 1.
Monitoring Requirements	Surface water and groundwater monitoring required for compliance.	Same as Alternative 1.	Same as Alternative 1.	Same as Alternative 1.	Same as Alternative 1.	Same as Alternative 1.	Ongoing surface water monitoring as required per MPDES permit.
Costs							
Capital	$1,679 million	$261 million	$71 million	$78 million	$66 million	$55 million	--
Annual O&M	$283,000	$301,000	$300,000	$293,000	$284,000	$270,000	--
Present Worth	$1,191 million	$241 million	$71 million	$77 million	$66 million	$55 million	--

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Table ES-12
SUMMARY OF COMPARATIVE ANALYSIS OF ALTERNATIVES

Overall Protectiveness	Compliance with ARARs	Long-Term Effectiveness	Reduction of Toxicity Mobility, and Volume	Short-Term Effectiveness	Implementability	Cost
All alternatives except 6 and 7 address all of the identified ARARs and human health concerns. Alternative 1 is the most protective in terms of the pond bottom sediments because it includes solidification as treatment. Alternative 2 protects the pond berms more than the remaining alternatives (full PMF vs. partial PMF). Alternatives 1 and 2 provide the greatest level of treatment for surface and groundwater. Alternatives 3 and 4 are not as protective for flows >600 cfs. Alternatives 5 and 6 only provide improved treatment for average flows. Alternative 1 is the most protective against tailings and contaminated soils by providing treatment. Alternative 2 removes the risk from the site but does not treat the material. Alternatives 3, 4, and 5 cap the material onsite, but Alternative 3 is the most protective because it consolidates the material. Alternative 6 is the least protective of the action alternatives, isolating the material through flooding but not permanently treating or immobilizing it.	See Table ES-13	Alternative 1 has the least residual risk through the treatment of tailings, sludges, and sediments. Threats associated with the presence of untreated tailings and sediments are minimized. Alternative 2 has the least residual risk of the alternatives that do not eliminate the current pond system because it protects the ponds against a full PMF. The remaining action, alternatives are equal in terms of controlling residual risk from the pond sediments. They all protect the ponds against a full MCE and a partial PMF They differ in the level of water treatment. The risk of untreated water flowing out of the operable unit increases with each alternative from 3 to 7. The onsite residual risks from contaminated soils and tailings are minimized in Alternatives 1 and 2. Alternative 3 reduces the residual risk by consolidating the material. Alternative 6 contains the greatest residual risk of the action alternatives because of a lack of treatment for surface water flows above 120 cfs and the potential mobility of tailings and soils onsite.	Only Alternative 1 includes treatment of pond bottoms as part of the remediation. The remaining action alternatives limit the mobility of the sediments. No alternative addresses the volume of pond bottom sediments. Alternatives 1 and 2 provide the greatest reduction in toxicity and volume of contaminated surface and groundwater. Alternatives 3, 4, 5, and 6 treat portions of the water flow to reduce its toxicity and the volume of contaminants, but with a decreasing effectiveness. Alternative 6 provides the least reduction in surface water toxicity, improving treatment only for average and less-than-average flowing out of the operable unit. Alternative 1 treats the tailings and contaminated soils at the site to reduce their mobility. The remaining alternatives contain actions to reduce the mobility of the material, but they do not include direct treatment. Alternative 2 removes the material from the site. Alternative 3 provides the best onsite containment using consolidation and a RCRA-equivalent cap.	None of the alternatives will significantly affect the Warm Springs community during implementation. It is likely that construction in the tailings and contaminated soil would result in some local airborne releases of the material, but this is not expected to affect the town of Warm Springs. Remediation contractors would have to be protected against dermal and inhalation threats while working in areas containing tailings and contaminated soils. These threats could be controlled using masks and protective clothing. This applies to all alternatives. All six alternatives will require planning to protect a pair of bald eagles living within the operable unit. Only Alternative 1 would substantially impact potential eagle habitat. Alternative 1 would take about 17 years to complete because of the large volume of pond sediments requiring solidification. The remainder of the alternatives would take 2 to 5 years to complete. The wetlands system included in Alternatives 5 and 6 may take up to 5 years of startup to meet the operational objectives.	The majority of components proposed for the alternatives are well developed and expected to be easily implemented at the Warm Springs Ponds site. This includes all pond berm stabilization, groundwater collection, surface and groundwater treatment, and soils excavation and/or containment. In situ solidification (Alternative 1) and wetlands treatment (Alternatives 5 and 6) are innovative technologies much less developed and predictable than the other components. In situ solidification has not been used for waste stabilization, and its effectiveness, completeness, and permanence are not known for certain. Pilot tests would be required prior to initiation to verify its feasibity. Wetlands treatment has been used with varying degrees of success in treating acid mine drainage. Based on those results, its use here is expected to be feasible, although the startup period needed to establish good operation may require up to 5 years. All seven alternatives need an MPDES permit for pond discharge.	Annual operation and maintenance costs are almost equal (about $300,000) for the six action alternatives. Present worth costs are as follows: Alt. 1--$1.19 billion Alt. 2--$241 million Alt. 3--$71 million Alt. 4--$77 million Alt. 5--$66 million Alt. 6--$55 million Alt. 7--the no-action alternative, has no costs beyond existing operations

Table ES-12 (continued)

Overall Protectiveness	Compliance with ARARs	Long-Term Effectiveness	Reduction of Toxicity Mobility, and Volume	Short-Term Effectiveness	Implementability	Cost
				Alternative 1 would have a greater impact on the surrounding environment than any of the other alternatives because of the replacement of the present pond system. This would eliminate a substantial amount of wetland habitat.		
		Operations, maintenance, and monitoring requirements would be fairly equal for all six action alternatives due to similar surface and groundwater treatment schemes for all alternatives. All six action alternatives would require continued surface and groundwater monitoring. The majority of O&M tasks are related to operation of the surface water treatment system, a component present in all alternatives. The wetlands treatment system (Alternative 5 and 6) will increase O&M during startup, but this will decrease once the system is operating to design specifications. Permanence is greatest for most comprehensive actions (e.g., solidification and flood impoundment).			The remaining alternatives would temporarily affect the wetland habitat, but it would, for the most part, be restored. All six action alternatives would convert rangeland habitat to a flood impoundment or settling pond. The settling pond (Alternatives 3-6) would alter less land (500 acres vs. 1,000 acres) than the flood impoundment. Alternatives 5 and 6 would increase the wetland habitat onsite through the construction of a wetlands treatment system.	The equipment and materials required for the majority of the components are readily available. The exceptions are the machinery needed for in situ stabilization (4 to 6 months to fabricate), and an adequate supply of riprap. The riprap may have to be quarried specifically for this job, which is a feasible alternative.	

Table ES-13
ALTERNATIVE DESIGN
COMPLIANCE SUMMARY FOR FEDERAL AND MONTANA ARARs

ARAR Subject	Montana Statutory/ Regulatory Section	Description of Provision	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6	Alternative 7
Surface Water	ARM16.20.622	Ambient surface water quality standards for Montana's C-2 classification	Yes, could treat 4,000 cfs[b]	Yes, could treat 4,000 cfs[b]	Yes[c]	Yes[c]	No[d]	No[d]	No[e]
	ARM16.20.622	Waste treatment requirements for point source discharges to receiving waters	Yes, could treat 4,000 cfs[b]	Yes, could treat 4,000 cfs[b]	Yes[c]	Yes[c]	No[d]	No[d]	No[e]
	ARM16.20.203	Maximum contaminant levels for inorganic chemicals in potential community water systems	Yes, could treat 4,000 cfs[b]	Yes, could treat 4,000 cfs[b]	Yes[c]	Yes[c]	No[d]	No[d]	No[e]
	40 CFR 122-125	NPDES monitoring requirements	Yes	Yes	Yes	Yes	Yes	Yes	No
	40 CFR 125.130(b)	Best Management Practice	Yes	Yes	Yes	Yes	Yes	Yes	No
	40 CFR Parts 230 and 231	Dredge and fill requirements	Yes	Yes	Yes	Yes	Yes	Yes	NA[f]
Air	ARM16.8.815	Montana air standard for lead	Yes	Yes	Yes	Yes	Yes	Yes	NA
	ARM16.8.818	Montana particulate air standard	Yes	Yes	Yes	Yes	Yes	Yes	NA
	ARM16.8.821	Montana PM-10 standard	Yes	Yes	Yes	Yes	Yes	Yes	NA
	ARM16.2.1401(4)	Montana 20% opacity standard	Yes	Yes	Yes	Yes	Yes	Yes	NA
	40 CFR Part 50	National primary and secondary ambient air quality standards	Yes	Yes	Yes	Yes	Yes	Yes	No
	40 CFR Part 61	National emission standards for hazardous air pollutants	Yes	Yes	Yes	Yes	Yes	Yes	No
Groundwater	ARM16.20.1003	Montana Class II groundwater quality standards	Yes	Yes	Yes	Yes	Yes	Yes	No
Floodplain Management	ARM36.15.606	Criteria for flood control works allowed within designated floodways	Yes	Yes	Yes	Yes	No	No	No

Table ES-13 (continued)

ARAR Subject	Montana Statutory/ Regulatory Section	Description of Provision	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6	Alternative 7
	ARM36.2.404	Evaluation criteria for Natural Streambed and Land Preservation Act (1975) standards and guidelines	Yes	Yes	Yes	Yes	Yes	Yes	No
	40 CFR 6 (App. A) Exec. Order 11,988	Floodplains Management	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	40 CFR 6 (App. A) Exec. Order 11,990	Protection of Wetlands	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Dam Safety	ARM36.14.501	Design criteria for high hazard dams	Yes	Yes	Yes	Yes	Yes	Yes	NA
	ARM36.14.502	High hazard dam inflow design criteria	Exceeds ARAR	Exceeds ARAR	Yes	Yes	Yes	NA	NA
Reclamation	ARM26.4.505	Requires adequate cover over waste materials to prevent salt migration, adverse plant effects, and water pollution	Yes	Yes	Yes	Yes	Yes	Yes	No
	ARM26.4.520	Criteria for disposal of soil materials (tailings and contaminated soils)	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	ARM26.4.633	Requires that all surface drainage from disturbed areas be treated by the best available technology	Yes	Yes	Yes	Yes	Yes	Yes	No
	ARM26.4.642	Permanent impoundment construction and operation requirements	Yes	Yes	Yes	Yes	Yes	NA	NA
	ARM26.4.711	Revegetation actions must establish a diverse, effective, and permanent cover capable of self-regeneration and plant succession	Yes	Yes	Yes	Yes	Yes	Yes	NA
Hazardous Waste	ARM16.4.701-ARM16.4.703	Incorporation of federal regulatory requirements that establish the standards for permitted hazardous waste management facilities	Yes	Yes	Yes	Yes	Yes	Yes	No
Solid Waste	ARM16.14.505	Siting criteria for solid waste disposal disposal sites	Yes	Yes	Yes	Yes	Yes	Yes	No
	40 CFR Part 257	Criteria for solid waste classification and disposal	Yes	Yes	Yes	Yes	Yes	Yes	No

Table ES-13 (continued)

ARAR Subject	Montana Statutory/ Regulatory Section	Description of Provision	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6	Alternative 7
Occupational Safety	29 USC 651-678	Occupational Safety and Health Act	Yes	Yes	Yes	Yes	Yes	Yes	No
Historic Preservation	16 USC 469 40 CFR 6.301(c)	Archaeological and Historic Preservation Act	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	16 USC 470 40 CFR 6.301(b) 36 CFR Part 800	National Historic Preservation Act	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	16 USC 461-467 40 CFR 6.301(a)	Historic Sites, Buildings, and Antiquities Act	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	16 US 1531-1566 40 CFR 6.302(g)	Fish and Wildlife Coordination Act	Yes	Yes	Yes	Yes	Yes	Yes	No
Natural Resource	16 USC 1531-1543 50 CFR Parts 17 & 402 40 CFR 6.302(h)	Endangered Species Act	Yes	Yes	Yes	Yes	Yes	Yes	No
	40 CFR 6(App.A)	Protection of Wetlands	Yes	Yes	Yes	Yes	Yes	Yes	No

[a] ARAR compliance indicates that the requirements stated will be met with the exception that ambient water quality standards for arsenic and mercury will not be met under any alternative and will require a waiver based on technical impracticability, as discussed in Chapter 8.
[b] 4,000 cfs is a 100-year flood event on Silver Bow Creek
[c] Alternatives 3 and 4 could treat pond in-flows up to 600 cfs. This magnitude of flow is expected to be exceeded once every 2 years.
[d] Alternatives 5 and 6 could treat pond in-flows up to 210 cfs. This magnitude of flow is expected to be exceeded once each year.
[e] Current operating procedures result in the exceedance of water quality standards about 40 percent of the time.
[f] NA = not applicable.

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Table ES-14
COST ESTIMATES FOR THE ACTION ALTERNATIVES

Cost Components	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6
Estimated Construction Cost	$1,665,000,000	$250,000,000	$60,100,000	$65,500,000	$56,000,000	$46,100,000
Engineering Design	4,000,000	4,000,000	4,200,000	4,600,000	3,900,000	3,200,000
Services During Construction	7,000,000	4,000,000	4,200,000	4,600,000	3,900,000	3,200,000
Administrative and Legal	3,000,000	3,000,000	3,000,000	3,300,000	2,800,000	2,300,000
Total Project Cost	1,679,000,000	261,000,000	71,500,000	78,000,000	66,600,000	54,800,000
Operation and Maintenance (Yearly Costs)	283,000	301,000	300,000	293,000	284,000	270,000
Total Present Worth Cost	$1,191,500,000	$241,500,000	$71,100,000	$77,000,000	$66,300,000	$55,100,000

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Chapter 1
INTRODUCTION

PURPOSE OF THE FEASIBILITY STUDY

The primary purpose of a feasibility study is to 1) identify a broad range of potential alternatives for remedial action; 2) compare the alternatives to assess their feasibility in terms of effectiveness, implementability, and cost; and 3) evaluate, in detail, several of the most feasible alternatives both individually and against one another. All of this must be accomplished within the framework of Superfund and its implementing regulations prescribing the method for a feasibility study.

Superfund requires the selection of a remedial action that protects human health and the environment, is cost-effective, and uses permanent solutions and alternative treatment technologies or resource recovery technologies "to the maximum extent practicable."[1] Additionally, the Superfund process is designed to favor selection of remedial actions that "permanently and significantly reduce the volume, toxicity, or mobility of the hazardous substances, pollutants, and contaminants."[2] The remedy must also comply with applicable or relevant and appropriate requirements (ARARs) or invoke appropriate waivers of those ARARs.

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1 CERCLA § 121(b)(1), 42 USC § 9621(b)(1).

2 Id.

To achieve these statutory requirements, the USEPA has established a process for conducting feasibility studies and developing remedial action alternatives.[3] The process occurs in a series of steps, described and followed in this report, documenting the rationale for developing and evaluating the alternative approaches for site cleanup. Each step results in successively more specific definitions of potential remedial activities. The entire Superfund process is shown in Figure 1-1.

ORGANIZATION OF THE REPORT

This report begins with a description of the Warm Springs Ponds, including a summary of the results of the remedial investigation of the operable unit. This is presented in Chapter 2. The site information is followed by a summary in Chapter 3 of the legal standards governing site cleanup activities (ARARs), based on existing conditions in the Warm Springs Ponds Operable Unit. Chapter 3 also contains a summary of the Public Health and Environmental Assessment (PHEA) prepared for the operable unit. The PHEA serves as a baseline risk assessment and illustrates the consequences of taking no remedial action. The entire PHEA is contained in Appendix A. The potential ARARs are described in greater detail in Appendix B.

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[3] USEPA, 1988. Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA, (Interim Final, October 1988).

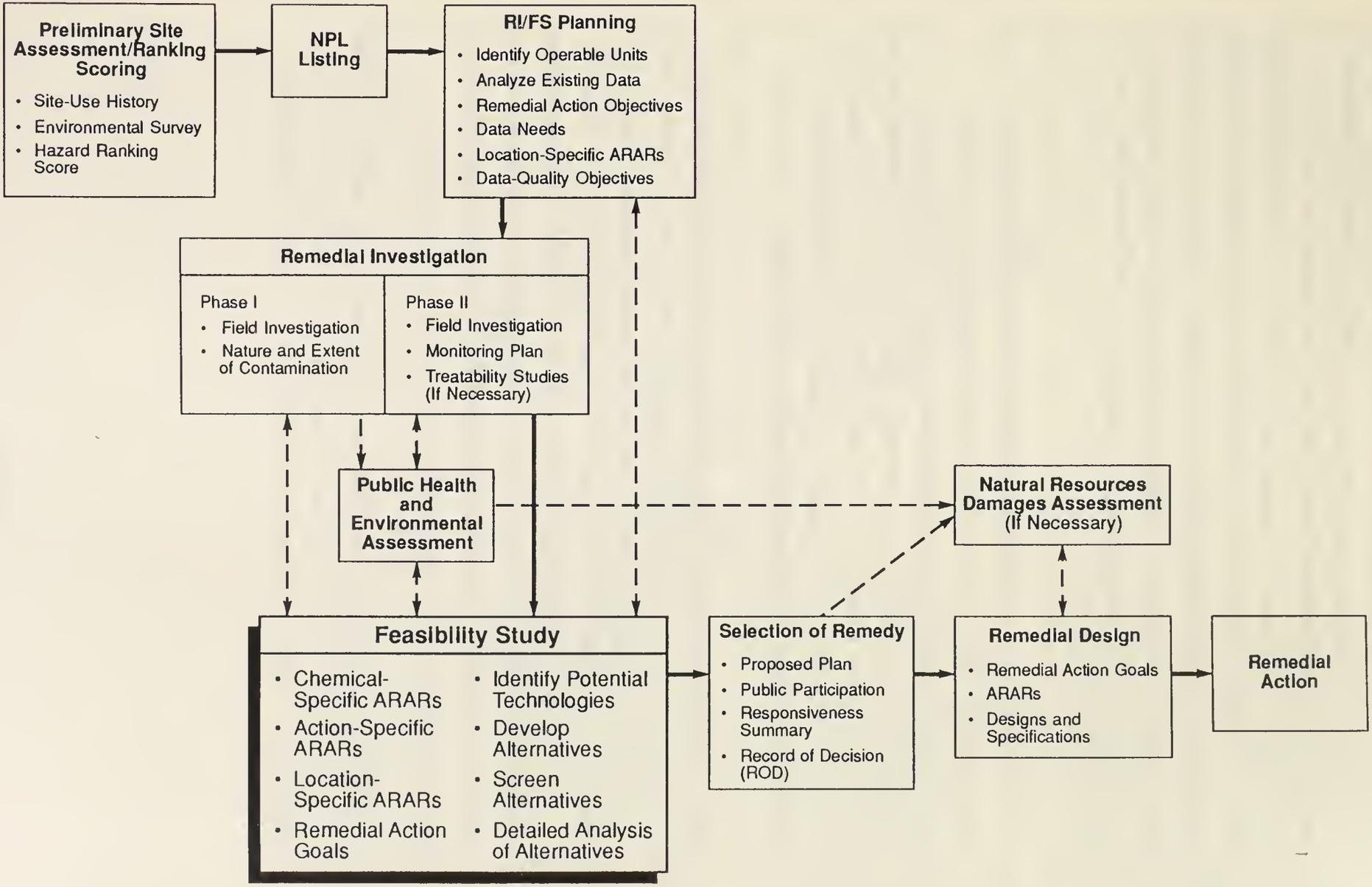

FIGURE 1-1

THE SUPERFUND PROCESS
WARM SPRINGS PONDS OPERABLE UNIT
FEASIBILITY STUDY

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The remainder of the feasibility study serves as the mechanism to develop, screen, and evaluate in detail the potential remedial alternatives. Based on the results of the site investigations, the identification of state and federal applicable or relevant and appropriate requirements, and the Public Health and Environmental Assessment, Chapter 4 identifies eight major, discrete environmental and human health problems potentially requiring remediation at the Warm Springs Ponds Operable Unit.

Chapter 5 identifies remedial action objectives for the ARARs exceedances and the eight environmental and human health problems at the Warm Springs Ponds Operable Unit. Where appropriate, these objectives specify the contaminants of concern (certain metals), the media (e.g., groundwater, surface water, soils) affected, exposure pathways, and acceptable contaminant levels (based on the ARARs).

The study then identifies "general response actions" that could potentially satisfy the remedial action objectives and ARARs. General response actions include activities such as containment, treatment, or removal of contaminants. For example, various general response actions exist for addressing contaminated soil. Soil can be excavated and moved to a safer place (removal), confined in place (containment), or treated to mitigate its harmful qualities (treatment).

After identifying general response actions, available technical approaches for carrying out the general response actions are identified. This occurs in Chapter 6. The available

technical approaches are called remedial technologies and process options.[4] Generally, more than one means exists to carry out a general response action. For example, contaminated soil could be contained in place by designing a cover to protect the soil from wind, rain, floods, and other forces that could cause it to move. Such a cover is called "capping," and is just one example of a remedial technology. Several types of materials or "caps" may be feasible, such as native soils, plastic sheets, or concrete; these make up the process options. Thus, process options are more specific examples of a remedial technology.

The identification of possible remedial technologies and process options occurs by first identifying an exhaustive list and then eliminating those that are either unrelated to the problems at the site or technically infeasible for use at the site. The study then evaluates and screens the remaining process options and finally selects one or more representative process options for each technology type retained for consideration. Specific process options are selected at this point so that a manageable number of remedial action alternatives can be developed later in the feasibility study.[5] Other process options may be considered again during later stages of the Superfund process, such as at the design stage.

The process options become the building blocks for site remediation. In Chapter 6, groups of process options are

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4 Ibid.

5 Ibid. 4-4 and 4-21.

combined to address the ARARs or problems of each of the environmental media. These groups of process options are called media-specific actions. Chapter 7 then develops the media-specific actions in more detail. It presents specific examples of the actions with enough refinement and detail to enable the USEPA, the State, and the public to make a meaningful selection. For each media-specific action, Chapter 7 identifies structures that would have to be built; wastes that would have to be removed, contained, or treated; preliminary details of required treatment processes; and other engineering details.

The final step in this feasibility study is the assembly and evaluation of comprehensive remedial alternatives for the entire operable unit. In Chapter 8, the comprehensive alternatives are assembled by combining media-specific actions into overall remediation packages.

To the extent possible and appropriate, the feasibility study developed at least one remedial alternative in each of the following five categories: 1) treatment or disposal at an offsite facility; 2) attainment of applicable or relevant and appropriate requirements; 3) exceedance of applicable or relevant and appropriate requirements; 4) reduction of the likelihood of present or future threat from the hazardous substances, which provides significant protection to public health and welfare and the environment, although not attaining applicable or relevant and appropriate requirements; and 5) a no-action alternative.[6] Additionally, the alternatives employ alternative treatment technologies and resource

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6 40 CFR § 300.68(f)(1).

recovery technologies "to the maximum extent practicable"[7] and "consider and integrate waste minimization, destruction, and recycling," as appropriate.[8]

The alternatives are evaluated in Chapter 8, both individually and in relation to each other, against the following nine criteria developed by the USEPA:

1. Overall protection of human health and the environment

2. Compliance with applicable or relevant and appropriate requirements

3. Long-term effectiveness and permanence

4. Reduction of toxicity, mobility, or volume of the wastes

5. Short-term effectiveness

6. Implementability

7. Cost

8. Acceptability of each alternative to the support agency

9. Acceptability of each alternative to the public[9]

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7 CERCLA § 121(b)(1), 42 USC § 9621(b)(1).

8 40 CFR § 300.68(f)(2).

9 USEPA, 1988. 6-3 to 6-4.

The last two criteria are not addressed in detail in the feasibility study; rather, they will be addressed in the Record of Decision, following public comment on the Public Review Draft Feasibility Study. In addition to the nine criteria identified by the USEPA, Superfund favors the use of alternative treatment technologies and resource recovery technologies. Chapter 8 discusses whether and the degree to which the alternatives meet these additional statutory criteria.

SCOPE OF THE FEASIBILITY STUDY

Because of the geographic, technical, and legal relationships among the Superfund sites in the Clark Fork River Basin, remedial actions at any site or operable unit must be coordinated with those at other locations. As one example, remedial actions that are upstream, upgradient, or upwind must avoid recontaminating downstream, downgradient, or downwind locations that have already been remediated. Sequencing of remedial activities, therefore, is critical to maximize efficiency, cost-effectiveness, and environmental protectiveness of each remedial action.

This feasibility study for Warm Springs Ponds takes into account that later remedial actions at other locations will affect the ultimate achievement of permanent and significant reduction of hazardous substances, pollutants, and contaminants within the boundaries of the Warm Springs Ponds Operable Unit. For example, future removal or containment of tailings deposits from the floodplain of Silver Bow Creek (upstream of the ponds) will have a tremendous impact on the longevity of the pond system and the effectiveness of some of the remedial actions in the Warm Springs Ponds Operable

Unit. Consequently, this feasibility study clearly identifies those problems, such as tailings deposits, that cannot be entirely remedied by actions taken at Warm Springs Ponds, and that will require additional remedial activities at other locations.

In summary, this feasibility study is a detailed technical and legal report prepared by the Montana Department of Health and Environmental Sciences with guidance from the USEPA. It identifies remedial action alternatives for the Warm Springs Ponds Operable Unit from a technical or engineering perspective. The feasibility study does not recommend any particular alternative. Rather, the selection of the appropriate extent of remedy is left to the USEPA and the State environmental agencies on the basis of information contained in this report, the administrative record, public comment on this report, and the relevant statutory and regulatory requirements.

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Chapter 2
SITE DESCRIPTION AND CONTAMINATION CHARACTERISTICS

INTRODUCTION

This chapter provides background information on the Warm Springs Ponds, including their history and physical characteristics. It also describes the nature and extent of contamination found at the site during the remedial investigation. In describing the nature and extent of contamination, the chapter considers contaminant types, quantities, chemical and physical properties and concentrations, as well as pathways of contaminant movement. The chapter also reviews previous studies of potential remedial actions at the site. Summaries of the Phase I remedial investigation for the area, performed by MultiTech in 1987, as well as the Phase II remedial investigation, completed by CH2M HILL in 1989, are contained in separate documents.[1] Additional detail on many of the points summarized in this chapter is available in the two remedial investigations reports.

The remedial investigations consisted of data collection and site characterization to determine the nature and extent of risks to human health and welfare and the environment presented by conditions at and operation of the Warm Springs Ponds. Data collection included compiling and evaluating

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[1] Phase I Remedial Investigation Report by MultiTech (1987) is available for review at the following libraries: University of Montana in Missoula; Montana State University in Bozeman; Montana College of Mineral Science and Technology in Butte; Montana State Library in Helena; Butte-Silver Bow Public Library; and the Grant Kohrs Ranch in Deer Lodge. For further information as to other administrative record repositories, contact the Montana Department of Health and Environmental Sciences Public Information Office in Helena at 406/444-2821 or 1-800/648-8465 (toll free in-state).

Phase II Remedial Investigation Data Summary by CH2M HILL (1989) is available for review at the same locations noted above.

existing information, sampling, monitoring, and assessing exposure levels. The necessity for and proposed extent of remedial actions for the site are based in part on the findings of the remedial investigation.[2]

In accordance with the federal regulations developed to implement Superfund, the remedial investigation assessed the following factors, as necessary, to determine the appropriate cleanup action for the site:

- Population, environmental, and welfare concerns at risk
- Routes of exposure
- Amount, concentration, hazardous properties, environmental fate and transport (i.e., persistence, mobility, and ability and opportunity to bioaccumulate), and form of the substances present
- Hydrogeological factors (including soil permeability, depth to saturated zone, proximity to drinking water aquifer, etc.)
- Current and potential groundwater use
- Climate
- Identification and characterization of the sources of contamination
- Whether substances at the site may be reused or recycled

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[2] 40 CFR § 300.6 and 300.68(d).

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- The likelihood of future releases if the contaminated substances remain on site

- The extent to which natural or manmade barriers currently contain the substances, and the adequacy of those barriers

- The extent to which the substances have migrated or are expected to migrate, and whether future migration may pose a threat to public health or welfare or the environment

- Applicable or relevant and appropriate regulatory requirements, as well as other federal or state criteria, advisories, and guidance

- Air, land, water, or food chain contamination problems

- Other appropriate matters.[3]

The Warm Springs Ponds remedial investigation evaluated the foregoing factors, as appropriate. A summary of the results of the investigation are presented in the remainder of Chapter 2.

SITE BACKGROUND

The Warm Springs Ponds Operable Unit is approximately 13 air miles northwest of Butte, Montana, near the confluences of Silver Bow Creek, Mill Creek, Willow Creek, and Warm Springs Creek. The site covers approximately 2,500 acres; major

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[3] 40 CFR § 300.68(e) (2).

features include the three settling ponds, the wildlife ponds, and the Mill-Willow Bypass (see Figure ES-1).

The primary function of the Warm Springs Ponds has been to settle wastes in Silver Bow Creek that are derived from mining, milling, and smelting activities around the cities of Butte and Anaconda. Mining in the Butte area began with the discovery of placer gold in Silver Bow Creek in the summer of 1864. Several townsites and camps sprung up among the diggings. However, these operations were short-lived, and most of the miners left by 1869. Those who stayed began prospecting the quartz lode deposits of silver and the associated complex copper ores on the Butte Hill. Their efforts culminated in a silver rush, which began in the mid-1870s and revived the old camp. During that time, world-class deposits of copper ore were identified. By 1881, Butte had become one of the nation's major mining centers; the district attained national dominance in copper mining by the mid-1890s and international prominence by the turn of the century. Operations continued for over 100 years until 1980, when in response to a depressed copper market, Anaconda Minerals Company (AMC) closed all the underground mines and continued active mining only in the Berkeley Pit (established in 1955) and the East Berkeley Pit. In 1977, AMC merged with the Atlantic Richfield Company (ARCO). ARCO closed the Berkeley Pit in 1982 and the East Berkeley Pit in 1983.

To support mining, various smelting and milling facilities also operated in the Butte area. The first two facilities were erected in 1874 to smelt gold and silver. Ten years later, Marcus Daly, one of the founders of the Anaconda Minerals Company, built a copper smelter 27 miles west of Butte and planned the city of Anaconda. The Anaconda Smelter was moved to a new location near the city in 1900, and operated from 1903 to 1980.

From the beginning of ore concentrating and smelting activities in 1880 until 1911, mill tailings and other wastes from the Butte and Anaconda areas were carried down Silver Bow Creek to the Clark Fork River, at least as far as the Milltown Reservoir (built in 1907), approximately 145 river miles, and probably farther.[4] Milling and smelting operations adjacent to Silver Bow Creek generated an estimated total of 10 million tons of waste just from 1878-1925.[5] Contaminated wastewater from mining operations in Butte were discharged into Silver Bow Creek throughout its mining history. Dissolved metals from this source were carried downstream as well.

In 1911, AMC made the first attempt to control the amount of sediment and tailings carried into the Clark Fork River from Silver Bow Creek.[6] AMC built a 20-foot-high tailings dam on Silver Bow Creek near the town of Warm Springs, thus creating Warm Springs Pond 1 (Figure ES-1). Pond 1 is currently full of tailings and is no longer used as part of the treatment system.

In 1916, AMC built another 18-foot-high dam upstream from the first dam, thus creating Warm Springs Pond 2; this dam was raised to a height of 23 feet during 1967-1969.[7]

Warm Springs Ponds 1 and 2 trapped and settled out sediment from Silver Bow Creek. The primary sources of this sediment

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4 Moore, J.N, 1985. Source of Metal Contamination in Milltown Reservoir, Montana: An Interpretation Based on Clark Fork River Bank Sediment. Prepared for U.S. Environmental Protection Agency, Helena, Montana.

5 MultiTech, 1987.

6 Hydrometrics, 1983. Summit and Deer Lodge Valleys Long-Term Environmental Rehabilitation Study, Warm Springs Ponds, Butte-Anaconda, Montana, Volume VII. Prepared for the Anaconda Minerals Company, Butte, Montana.

7 Id.

consisted of continued milling operations in the Butte area, previously deposited tailings eroded from upstream deposits in and along the Silver Bow Creek channel, mine water discharge, and increased natural sedimentation resulting from vegetation disturbance.[8] Overflow discharge of water from the nearby Anaconda and Opportunity Ponds at the Anaconda Smelter (Figure ES-3) also may have contributed sediments, because this water flows into Silver Bow Creek above the Warm Springs Ponds.

AMC built a third, and much larger, 28-foot-high dam upstream of Pond 2 between 1954 and 1959, primarily for sediment control. This structure created Warm Springs Pond 3. The height of this dam was increased during 1967-1969 to 33 feet.[9]

In 1967, Warm Springs Pond 3 was converted from a simple sedimentation pond into a treatment pond to control discharges associated with the Weed Concentrator in Butte (the primary ore concentrator in the Butte area since 1963), precipitation plant spent solution from AMC's Butte operations, and overflow from the Opportunity Ponds. Treatment consisted of introducing a lime/water suspension into Silver Bow Creek above Warm Springs Pond 3. The addition of the lime suspension raised the pH of the creek water before it entered the ponds, thus facilitating the precipitation of dissolved metals in the Warm Springs Ponds.

The pond system currently does not directly receive wastes from ongoing milling activities in the Butte area. It is now operated as a treatment system for the flows (still

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8 MultiTech, 1987.

9 Hydrometrics, 1983.

contaminated) in Silver Bow Creek, serving both as a settling basin for entrained sediments and as a precipitation unit (using lime and biological enhancement) for removal of dissolved metal contaminants. Dry quicklime is added to Silver Bow Creek above Pond 3, primarily during the winter months, to raise the pH and facilitate precipitation of metal contaminants in Ponds 2 and 3. During the winter of 1987-1988 while the remedial investigation was conducted, the addition of lime to Silver Bow Creek was observed on at least two occasions.

Just west of the pond system and within the operable unit lies the Mill-Willow Bypass (Figure ES-1), parts of which were constructed in the late 1950s. The current configuration of the Mill-Willow Bypass was completed about 1969-1970 in conjunction with changes in the Pond 3 berm.[10] The purpose of the Mill-Willow Bypass is to route relatively less contaminated waters of Mill Creek and Willow Creek around the pond system and thus reduce the volume of water entering the pond system for treatment. The bypass also serves to convey excess water in Silver Bow Creek around the pond system during flows in excess of the present design maximum of approximately 700 cubic feet per second (cfs).

Material excavated to construct the channel was placed adjacent to the channel to create berms along the bypass. Visual observations of the bypass area suggest that upper reaches of the channel were constructed through tailings deposits on the historic Silver Bow Creek floodplain. The western berm between the Mill-Willow Bypass and Pond 3 (Figure ES-1) was raised by AMC in 1987 to keep high flows out of Pond 3.

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[10] Stevenson, Sam, 1988. Environmental Engineer, Anaconda Minerals Company. Personal communication.

The wildlife ponds were constructed about 1967 by the Montana Department of Fish and Game (now Fish, Wildlife and Parks) in association with AMC.[11] The purpose was to increase wildlife habitat in the upper Deer Lodge Valley. Two main ponds, with smaller ponds and islands, were constructed (Figure ES-1). Water within the wildlife ponds is obtained from Pond 3. The wildlife ponds discharge to the Mill-Willow Bypass. The dissolved metals concentration of water flowing through the wildlife ponds is reduced as the water moves through the series of cells comprising the ponds.

The Warm Springs Ponds system and the wildlife ponds are administered by ARCO and the Montana Department of Fish, Wildlife, and Parks.

A summary of available data on the three ponds is presented in Table 2-1.

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SITE DESCRIPTION

PHYSIOGRAPHY/DEMOGRAPHY

The Warm Springs Ponds Operable Unit is located near the upper end of the broad Deer Lodge Valley at an elevation of approximately 4,800 feet. It is located within the relatively flat, south-north trending floodplain of Silver Bow Creek near the eastern margins of the valley. Moderately steep foothills bound the site to the east. Areas west of the site are characterized by gently sloping topography associated with drainages emanating from the Flint Creek and Pintlar Ranges.

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[11] Stevenson, 1988.

Table 2-1
SUMMARY OF POND DATA FOR THE WARM SPRINGS PONDS OPERABLE UNIT

	Pond 1	Pond 2	Pond 3
Approximate Year Constructed	1911	1916	1959
Dike Crest Elevation (spot elevation)	4821	4835	4872.5
Dike Crest Width (feet)	14	19	18
Maximum Dike Height (feet)	20	23	33
Normal Water Surface Elevation	NA[a]	4831	4867.5
Water Surface Area at Normal Elevation (acres)	NA[a]	244	637
Maximum Water Surface Elevation	NA[a]	4835	4870.5
Water Surface Area at Maximum Elevation (acres)	NA[a]	422	927
Water Volume at Normal Elevation (acre-feet)	NA[a]	860	4,800
Inlet Hydraulic Capacity (cubic feet per second)	NA[a]	3,200	700
Outlet Hydraulic Capacity (cubic feet per second)	NA[a]	1,400	3,200
Normal Inflow Rate (cubic feet per second)	NA[a]	53	73
Eastern Drainage Area (square miles)	3.8	5.3	1.7
100-Year Flood Volume from Eastern Drainage (acre-feet)	77	203	268
100-Year Flood Flow from Eastern Drainage (cubic feet per second)	291	724	634
Probable Max. Flood Volume from Eastern Drainage (acre-feet)	2,200	3,000	1,000
Probable Max. Flood Flow From Eastern Drainage (cubic feet per second)	13,800	19,200	9,700
Downstream Dike Slopes (maximum)[b]	1.4:1	1.4:1	1.6:1

[a]Not applicable.
[b]Upstream dike slope not available.

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To the west of the Warm Springs Ponds Operable Unit lie the Opportunity Ponds (Figure ES-1). This hydrologic and geomorphic feature covers an area of approximately 3,500 acres. The Opportunity Ponds were used until 1980 to settle wastes derived from smelting activities at the Anaconda Smelter. The Opportunity Ponds are a part of the Anaconda Smelter Superfund site and are being evaluated under a separate investigation.

Two population centers west of the operable unit are the towns of Warm Springs (population approximately 300) and Opportunity (population approximately 750). The Warm Springs State Hospital is located in the town of Warm Springs. There are other isolated residences near the site, primarily along the foothills east of the pond system and farther down the valley along the Clark Fork River. Interstate 90 runs north-south along the west side of the operable unit (Figure ES-1). This highway is the major arterial route for motorists traveling east or west through western Montana.

CLIMATE

The Warm Springs Ponds Operable Unit has a continental climate with an annual average precipitation of 13.2 inches, as measured in nearby Anaconda. Climate in the higher mountain elevations surrounding the operable unit is alpine to subalpine. This climate is characterized by cold temperatures and heavy precipitation, often in the form of snow. Melting of the mountain snowpack in spring and early summer provides the majority of the surface water flows at lower elevations, including the flows through the Warm Springs Ponds Operable Unit.

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The Warm Springs Ponds are ice covered during the winter months. The area occasionally experiences midwinter thaws and subsequent high streamflows. Snow cover in the lower valleys usually melts in March to early April, with the mountain snowpack normally remaining through May and into June.

Average annual temperature in the vicinity of the Warm Springs Ponds is approximately 44°F. Average temperatures in July and December, as measured in nearby Anaconda, are 60°F and 24°F, respectively. Predominant wind direction in the vicinity is south to north. Average wind velocities are approximately 8 knots.

GEOLOGY

The Warm Springs Ponds are located along the eastern edge of a Tertiary-age, down-dropped block that formed the present Deer Lodge Valley. Tertiary deposits up to 5,000 feet thick are present within the Deer Lodge Valley north of the Warm Springs Ponds.[12] The geology of the surrounding uplands is characterized by Paleozoic limestone, shale, and quartzite units in the Flint Creek Range west of the site, and by quartz monzonite of the Boulder Batholith to the east. Silver Bow Creek enters the upper Deer Lodge Valley through volcanic units that outcrop south of the site.

Near-surface lithologies in the Warm Springs Ponds Operable Unit are characterized by relatively thin Pleistocene alluvial deposits and varying thicknesses of medium-grained mine

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[12] Noble, R.A., R.N. Bergantino, T.W. Patton, B. Sholes, F. Daniel, and J. Schofield, 1982. A map of Cenozoic Basin-Fill Deposits, Western Montana. Montana Bureau of Mines and Geology, MBMG 99 TF 100.50 West, Butte, Montana.

wastes. Glaciofluvial deposits are present near the surface and are occasionally intermixed with the alluvium.[13] These deposits typically include sand and gravel units separated by finer-grained material. Tertiary colluvial valley fill underlies these recent deposits. Tertiary colluvium typically consists of bedded clay, silt, sand, gravel, and occasional boulders.

SOILS

Soils in the vicinity are developed primarily on valley fill sediments under grassland vegetation. Shallow gravel-textured to deep fine-grained alluvial soils have developed adjacent to Silver Bow Creek and the Clark Fork River. Nutrient-rich organic soils of various depths are present in low or wetland areas.[14]

Much of the natural soil in the study area has been affected by mining wastes such as mill tailings and smelter wastes. Mining-related wastes are generally sandy textured, reflecting their granitic origin, and typically have high concentrations of metals and sulfide minerals. Tailings, waste rock, leach pond deposits, and smelter wastes are present throughout the site. These materials generally overlie natural colluvium or alluvium and range in thickness from less than 1 foot to several feet. The greatest expanses of these deposits are present at the upper (southern) ends of Ponds 2 and 3, within and below Pond 1, and along the Mill-Willow Bypass (Figure ES-1).

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[13] Konizeski, R.L., R.G. McMurtrey, and A. Brietkrietz, 1968. Geology and Groundwater Resources of the Deer Lodge Valley, Montana. United States Geological Survey Water Supply Paper No. 1862.

[14] Schafer, W.M, 1984. Silver Bow Creek Preliminary Remedial Technology Assessment: Tailings, Waste, and Sediment Section. Prepared for the Montana Department of Health and Environmental Sciences, Solid and Hazardous Waste Bureau, Helena, Montana.

SURFACE HYDROLOGY

The site is located just south of the historic confluence of Silver Bow and Warm Springs Creeks, which joined to form the Clark Fork River. Because of the construction of these settling ponds near the lower end of Silver Bow Creek, the area's natural hydrology has been altered. Silver Bow Creek currently enters Pond 3 from the south. Water is then routed into Pond 2 by two decant towers and into the wildlife ponds by siphons. Both Pond 2 and the wildlife ponds discharge into the Mill-Willow Bypass (Figure ES-3). The confluence of the Mill-Willow Bypass and Warm Springs Creek is defined as the start of the Clark Fork River. Flow into and out of Pond 1, which is no longer part of the treatment system, has been obstructed by berms. Seepage from Pond 2 into Pond 1 is periodically pumped back into Pond 2.

Because of the very low gradient south of the pond system, the waters of Silver Bow Creek and Willow Creek occasionally intermingle through connecting side channels. For this reason, a portion of the water in Silver Bow Creek does not flow through the pond treatment system and, instead, occasionally enters the Mill-Willow Bypass and ultimately the Clark Fork River without treatment.

The Warm Springs Ponds system reduces metals concentrations and removes sediments during average (73 cfs) or below average flow conditions in Silver Bow Creek, particularly during the warmer months. However, upsets occur in the current treatment system during high flow events in Silver Bow Creek when flows exceed the capacity of the inlet structure to Pond 3 (approximately 700 cfs). When this

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occurs, a fuse plug washes out and a majority of the water in Silver Bow Creek is routed directly to the Mill-Willow Bypass. This water reaches the Clark Fork River untreated. Such bypass situations also occur at flows less than 700 cfs when the inlet structure becomes clogged with debris, thus decreasing its capacity. This situation occurred at least twice during 1985-1987, the period during which the Phase I remedial investigation was conducted.

GROUNDWATER HYDROLOGY

The groundwater system in the Warm Springs Operable Unit is complex, owing to the heterogeneity of the unconsolidated geologic deposits in the area. Alluvial aquifers occur along present-day stream channels, but deposits hosting these aquifers are thin and generally do not extend laterally throughout the site.

Other aquifers are associated with Tertiary-age valley fill and the thick deposits of glaciofluvial material. Several water-bearing zones occur, typically associated with the presence of coarse-grained units. These aquifers generally exhibit moderate to low permeabilities and are probably connected on a regional scale, although fine-grained interbeds tend to confine deeper aquifers locally.

The site is in a groundwater discharge area for the upper Deer Lodge Valley, typified by shallow groundwater tables and swamps. The presence of artificially elevated surface water in the pond systems also affects groundwater elevations and movement within the site. Regional groundwater movement generally mirrors surface topography. Groundwater gradients along Silver Bow Creek and the upper Clark Fork River are to the north; inputs are received from the south-

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west in the vicinity of Mill, Willow, and Warm Springs Creeks and from the foothills to the east.

No domestic wells are located within the immediate vicinity of the Warm Springs Ponds Operable Unit. Several are located east of the pond system, but these wells are completed in bedrock units that do not appear to be affected by the pond system. The town of Warm Springs derives its water from supply wells constructed in unconsolidated Tertiary deposits from depths of approximately 200 feet. These wells appear to be supplied with water derived from groundwater resources west of and hydraulically isolated from the Warm Springs Ponds. (See Appendix A for more detailed information on groundwater use in the area.)

LAND USE

Approximately 1,000 acres of the 2,500 acres within the defined boundaries of the operable unit are taken up by open water associated with the pond system. Tailings deposits and contaminated soils cover about 420 acres within the operable unit (see Table 2-2). These areas are most prominent above Pond 3, between Ponds 2 and 3, within and below Pond 1, and along the Mill Willow Bypass. A small tract of land (approximately 35 acres) located on the east side of Pond 3 is being used to harvest grain for waterfowl feed, as part of the wildlife program (explained below). The remaining acreage within the operable unit is characterized by sparsely to well-vegetated grasslands and marshes.

The Montana Department of Fish, Wildlife, and Parks administers much of the area as a wildlife refuge. Because of the attraction of the pond area for water fowl and other wildlife, hunting activities are commonplace, particularly in the vicinity of Ponds 1 and 2. Anglers also frequent the

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Table 2-2
SUMMARY OF TAILINGS DEPOSITS AND CONTAMINANTED SOILS
AND POND BOTTOM SEDIMENTS--AREAS AND VOLUMES

	Area (acres)	Volume (acre-feet)	Volume (cubic yards)
Tailings Deposits and Contaminated Soils			
Mill-Willow Bypass			
Exposed Tailings	21	47	75,800
Vegetated Tailings and Contaminated Soils	33	80	130,000
	54	127	205,800
Area Above Pond 3			
Exposed Tailings	22	56	90,300
Vegetated Tailings and Contaminated Soils	268	700	1,130,000
	290	756	1,220,300
Area Below Pond 1			
Exposed Tailings	17	48	77,400
Vegetated Tailings and Contaminated Soils	59	246	397,000
	76	294	474,400
Total Tailings Deposits and Contaminated Soils	420	1,177	1,900,500
Pond Bottom Sediments			
Pond 1			
Exposed Sediments	59	455	734,000
Vegetated/Submerged Sediments	225	1,340	2,156,000
	284	1,795	2,890,000
Pond 2			
Exposed Sediments	155	800	1,300,000
Vegetated/Submerged Sediments	347	2,230	3,590,000
	502	3,030	4,890,000
Pond 3			
Submerged Sediments	665	6,930	11,180,000
Total Pond Bottom Sediments	1,451	11,755	18,960,000
Total Tailings, Soils, and Sediments	1,871	12,932	20,860,500

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area along the Mill-Willow Bypass and below Pond 2 and occasionally have been observed using boats in Pond 2.

Local residents also use the Warm Springs Ponds for recreational purposes, including hiking and bird watching. Access is limited primarily to foot traffic; locked gates limit vehicular access to the site.

NATURE AND EXTENT OF CONTAMINATION

Four contaminated media have been identified for the operable unit: the pond bottom sediments, the surface water, the tailings deposits and contaminated soils, and the groundwater. The patterns of contamination of each of these environmental media are the result of migration of the contaminants within and between them. A diagram that shows the areas of contamination and migration pathways is presented in Figure 2-1. The four environmental media are discussed in the following sections.

SEDIMENTS, TAILINGS, AND SOILS

Two of the media--the pond bottom sediments, and the tailings deposits and contaminated soils--contain the majority of the contaminants in the Warm Springs Ponds Operable Unit.[15] Tailings and pond bottom sediments are generally waste materials derived from historic mining and milling activities in the Butte and Anaconda areas. These materials are typically fine to coarse sand (reflective of their granitic origin) and generally contain metals associated

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[15] MultiTech, 1987.

with the sulfide ore body present near Butte. Pond bottom sediments, which include large amounts of tailings, are also comprised of precipitated hydroxides and oxyhydroxides (sludge) resulting from the addition of lime slurry to treat the water entering the pond system and from biologically mediated precipitation.

Tailings deposits and contaminated soils are present along Silver Bow Creek above Pond 3, below Pond 1, and along the Mill-Willow Bypass. Thicknesses of these deposits range from less than 1 inch to several feet. Tailings and contaminated soils are present within the operable unit in both exposed areas and in partially vegetated areas. Pond bottom sediments are contained within Ponds 1, 2, 3, and the wildlife ponds. These sediments cover an area of approximately 1,450 acres and range in thickness from less than 1 foot to over 20 feet.

Figure 2-2 shows the extent and approximate thicknesses of tailings and pond bottom sediments within the Warm Springs Ponds Operable Unit. The differentiation between tailings and pond bottom sediments is not distinct because the material types associated with each are similar. Figure 2-2 shows pond bottom sediments that are or were historically submerged. Tailings are those metals-enriched materials that are generally located adjacent to the current or historic floodplain of Silver Bow Creek and along the Mill-Willow Bypass. These materials are often intermixed with native soils and are present both in exposed areas and in areas that are partially to well vegetated.

Table 2-2 summarizes acreages and volumes of stream-deposited tailings and pond bottom sediments present within the Warm Springs Ponds Operable Unit. Sediment volume calculations are based upon interpretations of the spatial and

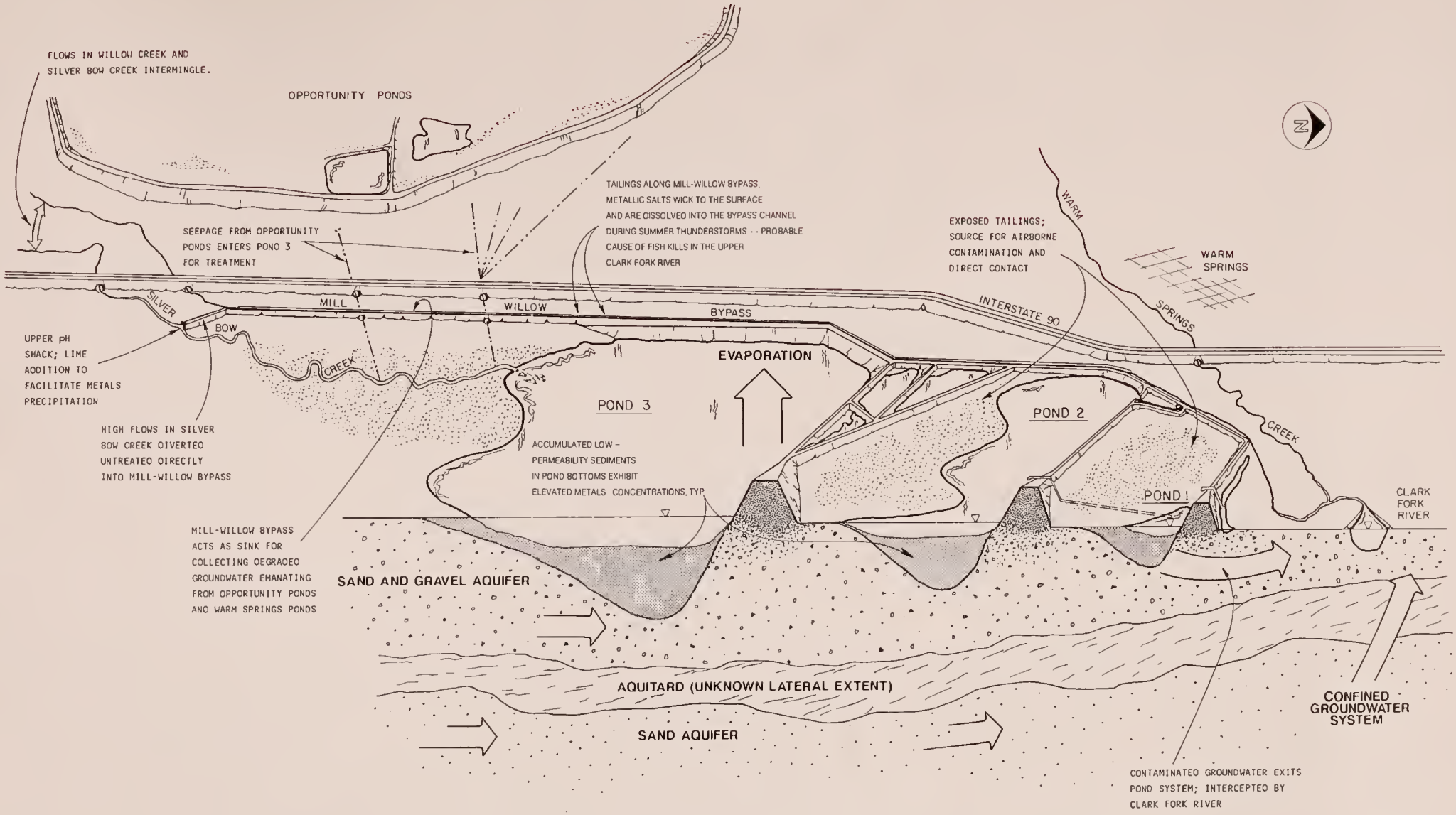

FIGURE 2-1

CONCEPTUAL MODEL OF CONTAMINANT MIGRATION PATHWAYS
WARM SPRINGS PONDS
FEASIBILITY STUDY

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FIGURE 2-2

TAILINGS/POND BOTTOM SEDIMENTS ISOPACH MAP
WARM SPRINGS PONDS
FEASIBILITY STUDY

vertical extent of the material through visual observation and through analysis of X-ray fluorescence data and laboratory-determined metals data.

Tailings Deposits and Contaminated Soils

Tailings along the Mill-Willow Bypass are most likely remnants of tailings deposition from the outflows of the Opportunity Ponds and tailings transported from the upper reaches of Silver Bow Creek during high flow events. Tailings along the bypass are predominantly sand-sized material. Tailings are visible throughout most of the course of the bypass within the active channel and along the first terrace adjacent to the channel. Contaminated soils are present between visible tailings deposits and mixed with the tailings.

Metallic salts are commonly present during summer months along the bypass at the surface of the tailings deposits. These salt deposits are derived from slow oxidation of the metal sulfides in the tailings deposits, which then wick to the surface during dry periods as soluble salts. These salts form crystalline deposits that dissolve during rainstorms and wash into the bypass. This phenomenon is probably responsible for the fishkills along the bypass and in the upper Clark Fork River that have historically occurred following summer thunderstorm events (see Chapter 4).

Analytical data for 50 surficial (0 to 1 inch) tailings and soils samples were collected at 43 sampling points within and adjacent to the Mill-Willow Bypass (Table 2-3). Sampling sites are shown on Figure 2-3. Analysis of these data and additional X-ray fluorescence data collected from the site indicate that the highest average metals concentrations occur on bare tailings areas located on the first terrace of the bypass. Average metals concentrations for tailings

Table 2-3

MILL-WILLOW BYPASS SEDIMENT STATISTICS

Parameter	No. of Samples	Mean[a]	Maximum[a]	Minimum[a]	Deviation[a]	Background[b]
Aluminum	50	9,621	34,400	3,810	6,332	--
Antimony	50	30	131	23	15	--
Arsenic	50	121	336	2	73	10
Barium	50	167	334	43	63	--
Beryllium	50	1	8	0	1	--
Cadmium	50	22	331	1	55	0.4
Calcium	50	25,489	201,000	1,540	36,720	--
Chromium	50	22	432	5	60	--
Cobalt	50	24	309	10	44	--
Copper	50	3,713	66,300	19	10,501	35
Iron	50	29,777	61,600	6,070	12,608	--
Lead	50	215	993	2	178	25
Magnesium	50	7,112	40,300	1,270	7,634	--
Manganese	50	2,370	23,700	173	5,055	250
Mercury	50	1	4	0	1	--
Nickel	50	22	233	9	34	--
Potassium	50	2,355	4,730	805	830	--
Selenium	50	2	9	2	1	--
Silver	50	5	17	3	2	--
Sodium	50	504	3,890	96	553	--
Thallium	50	1	5	1	1	--
Tin	50	18	79	14	9	--
Vanadium	50	26	102	7	15	--
Zinc	50	4,258	64,300	46	10,853	60
% Solids (wt. %)	50	87.1	99.3	19.7	13.5	--
Specific Conductance (umho/cm)	48	4,762.5	27,100.0	248.0	5,107.3	--
pH (pH units)	49	4.9	8.2	1.7	2.1	--

[a] All units are mg/kg unless otherwise noted.

b From Moore, 1985.

Notes: 1. Undetected parameters are assumed to be at the detection limit.

2. Statistics are computed from the results for natural samples.

Source: CH2M HILL, 1989.

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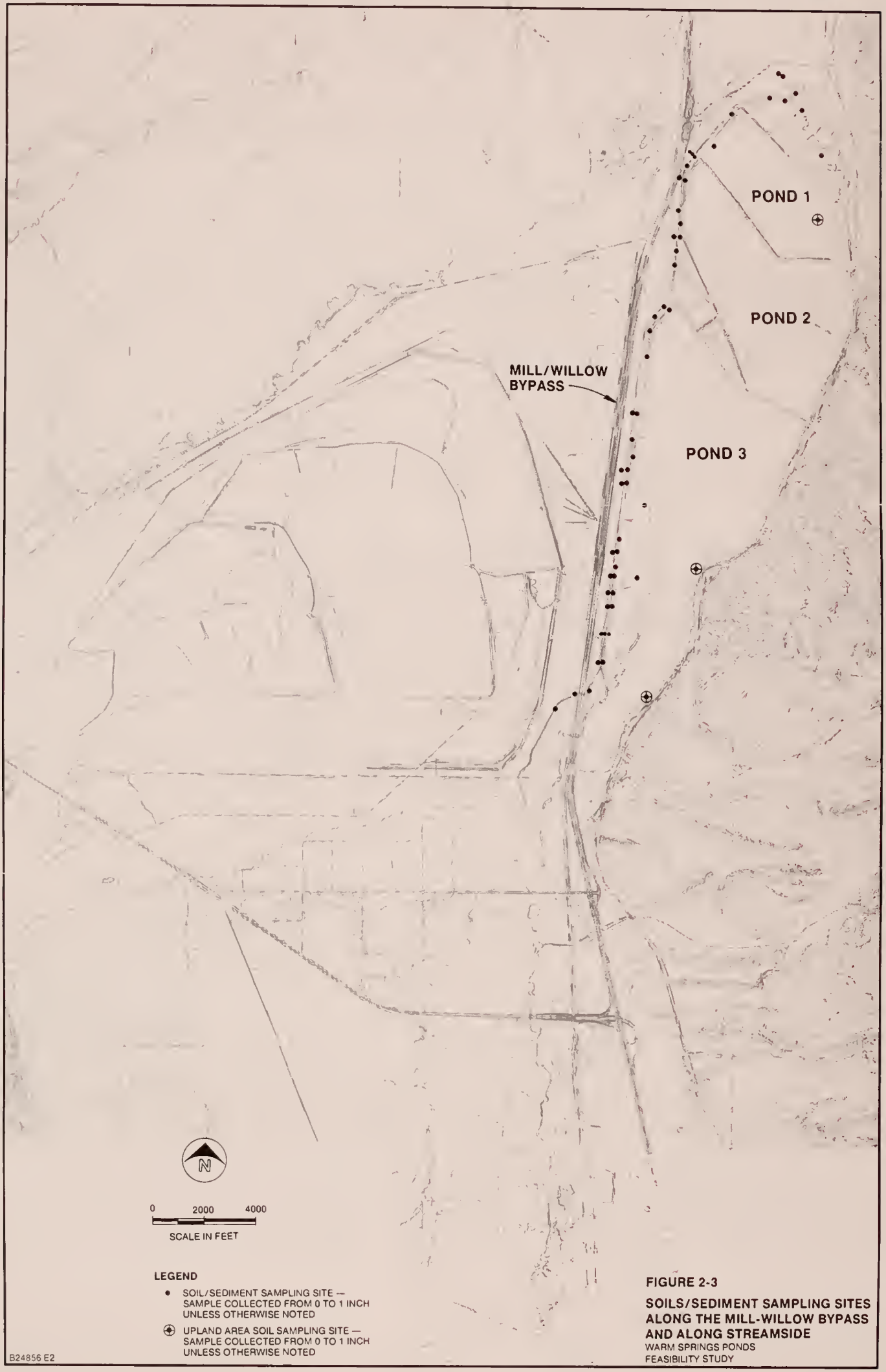

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FIGURE 2-3

SOILS/SEDIMENT SAMPLING SITES ALONG THE MILL-WILLOW BYPASS AND ALONG STREAMSIDE

WARM SPRINGS PONDS
FEASIBILITY STUDY

collected from bare areas on the first terrace (18 samples) were copper (8,656 mg/kg), zinc (9,589 mg/kg), and arsenic (126 mg/kg). (Other metals are listed in Table 2-3.) These values are considerably higher than area background concentrations reported for stream sediments outside the operable unit: copper (35 mg/kg), zinc (60 mg/kg), and arsenic (10 mg/kg).[16] Tailings and soil samples collected elsewhere along the bypass channel also contained metals concentrations in excess of reported background values.[17]

Analytical data and visual analysis of collected samples also indicate that finer-grained sediments (fine sand to silt) typically have higher concentrations of most metals. Coarser-grained material (larger than fine sand size) generally exhibited lower concentrations of most metals. Finer-grained materials are a significant contaminant source during runoff events caused by snowmelt or direct precipitation because of their erodibility and high metals contents.

Data for Mill-Willow Bypass soil samples collected during the Phase II remedial investigation[18] indicate metals in soils and tailings located along the bypass are soluble in water. Higher metals solubilities and lower pH values are generally associated with tailings samples collected in the upper one-third of the bypass. Metal-bearing sulfates and carbonate samples exhibited highest metals solubilities of soil/tailings samples collected. Available data indicate that contact of water with tailings material located along the bypass would solubilize metals and could adversely affect receiving surface water quality.

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16 Moore, 1985.

17 See Ibid.

18 CH2M HILL, 1989.

The volume of tailings along the Mill-Willow Bypass from its head to the northwest corner of Pond 1 is approximately 76,000 cubic yards (Table 2-2). Approximately 130,000 cubic yards of contaminated soils are present both adjacent to and underlying the tailings deposits. These volume estimates are based on aerial photography and field checks of the extent and depths of tailings and contaminated soils utilizing X-ray fluorescence spectrometry.

Other deposits of tailings and contaminated soil within the operable unit are generally similar to those in the bypass, and are located primarily along the historic course of Silver Bow Creek channel, near the east side of the present-day pond system. Surface expressions of these deposits are located along the Silver Bow Creek channel above Pond 3 and in the area below Pond 1 (Figure ES-1).

Tailings and soils samples were collected in the areas above Pond 3 and below Pond 1 at locations shown on Figure 2-3. A summary of analytical data for 11 samples collected at locations in these areas is contained in Table 2-4. These data and X-ray fluorescence data[19] obtained during sampling activities indicate that the lateral extent of metals contamination on the eastern side of these areas generally coincides with the slope break between the valley bottom and the adjacent foothills (Figure 2-2). Soil analyses for samples collected from upland areas (Table 2-4) supports this interpretation. The lateral extent of metals contamination on the western side of these areas generally parallels the historic Silver Bow Creek channel (Figure 2-2). Historic discharges from the Opportunity Ponds to the Warm Springs Ponds

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19 CH2M HILL, 1989.

Table 2-4
SUMMARY OF TAILINGS AND SOILS DATA FOR AREAS
ABOVE POND 3 AND BELOW POND 1
WARM SPRINGS PONDS AREA

	Tailings and Contaminated Soils Average Concentrations[a] (mg/kg)	Upland Soils Average Concentrations[b] (mg/kg)	Background Concentrations[c] (mg/kg)
Aluminum	8,537	9,670	--
Antimony	14.7	6.2	--
Arsenic	593	61	10
Barium	189	150	--
Beryllium	0.84	0.68	--
Cadmium	19.1	1.0	0.4
Calcium	63,400	5,622	--
Chromium	13.9	11.2	--
Cobalt	9.1	5.2	--
Copper	18,147	342	35
Iron	56,014	15,522	--
Lead	394	125	25
Magnesium	10,999	4,498	--
Manganese	1,669	312	250
Mercury	2.5	0.14	--
Nickel	15.2	8.1	--
Potassium	1,475	4,245	--
Selenium	1.0	0.16	--
Silver	15.2	2.8	--
Sodium	900	519	--
Thallium	0.3	0.3	--
Vanadium	17.7	23.2	--
Zinc	5,223	227	60

[a] Average concentrations from sediment samples WSP-111C, WSP-125D, WSP-134A, WSP-402A, WSP-405A, WSP-408A, and WSP-411A. Locations and analyses included in CH2M HILL, 1989. For values at the detection limit, the detection limit concentration was used in the average.

[b] Average concentrations from sediment samples WSP-100A, WSP-116A, WSP-215B, and WSP-300A. Locations and analyses included in CH2M HILL (1989). Upland soils obtained from sites above valley bottom.

[c] From Moore, 1985.

Source: CH2M HILL, 1989.

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probably affected soils in the area south of Pond 3 and west of Silver Bow Creek. The total area affected by metals contamination above Pond 3 is about 290 acres and below Pond 1 is about 76 acres (Table 2-2).

The depth of metals contamination in the tailings contaminated areas above Pond 3 and below Pond 1 was evaluated through visual analysis and through evaluation of x-ray fluorescence data for samples collected at vertical increments in the soil profile. These data indicate copper, zinc, cadmium, and arsenic concentrations typically decrease by 50 percent from above to below visually identified areas of contaminated material. This delineation was used to present thickness data on Figure 2-2. The combined volume of tailings and contaminated soils in the areas above Pond 3, below Pond 1, and along the Mill Willow Bypass is approximately 1.9 million cubic yards (Table 2-2).

Seven samples obtained from tailings areas above Pond 3 and below Pond 1 were analyzed for EP Toxicity metals concentrations. None of these samples exceeded the concentrations established to determine EP Toxicity.[20]

Pond Bottom Sediments

Pond bottom sediments were sampled at 34 sites throughout the ponds (Figure 2-4). At each site, multiple samples were taken with depth in the sediment profile. The samples were analyzed for total metals, common ions, cyanide, and percent solids (Table 2-5). A subset of the collected samples from Ponds 2 and 3 was analyzed for organic constituents. Analyses of these samples indicate organic constituents were

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20 CH2M HILL, 1989.

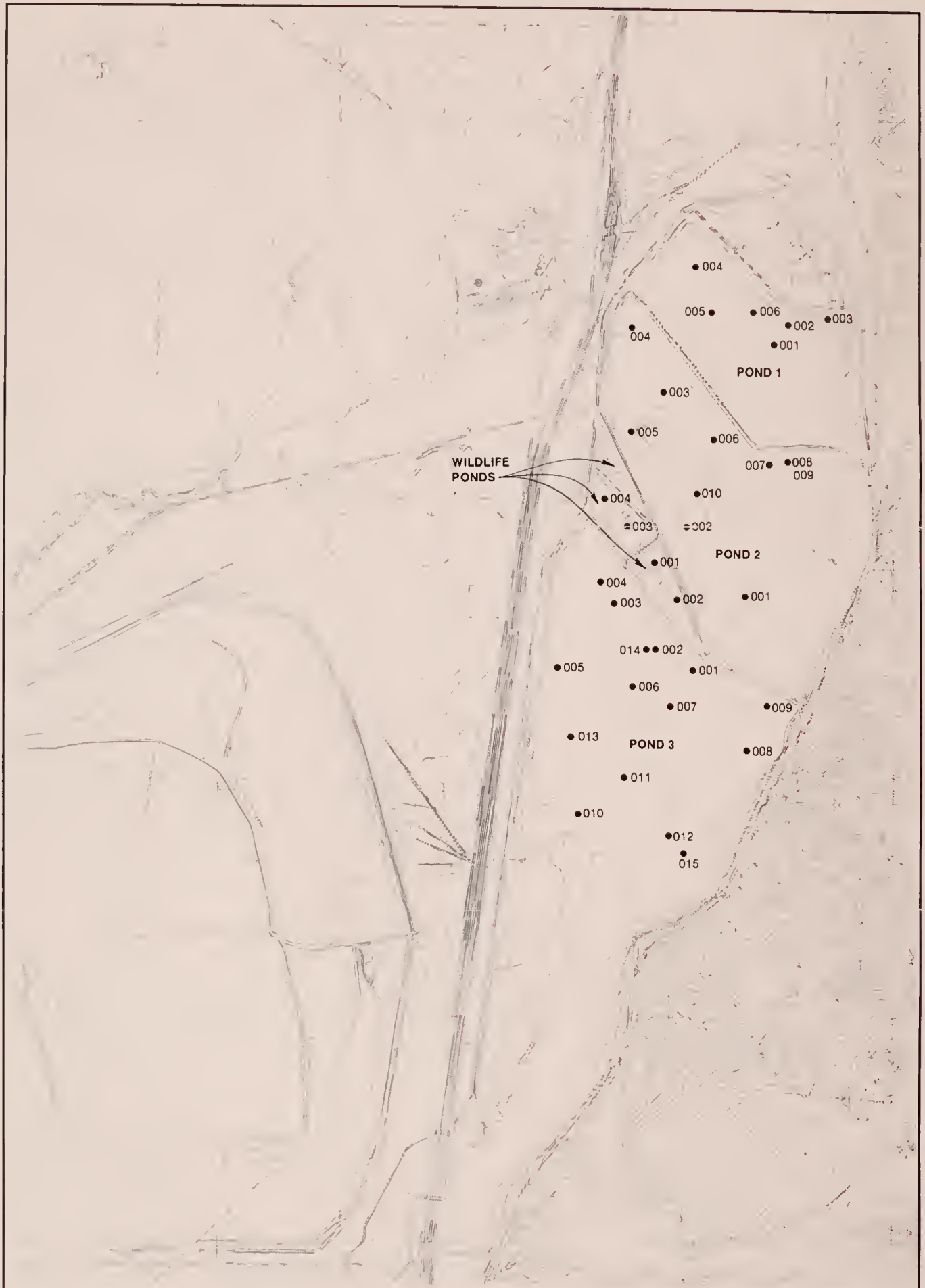

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FIGURE 2-4

POND BOTTOM SEDIMENT SAMPLING LOCATIONS

WARM SPRINGS PONDS
FEASIBILITY STUDY

Table 2-5
STATISTICAL ANALYSIS OF PARAMETERS MEASURED IN POND BOTTOM SEDIMENTS

Parameters	Overall Averages for Pond 1				Overall Averages for Pond 2				Overall Averages for Pond 3				Overall Average for Wildlife Ponds				
	No. of Samples	Minimum[a]	Maximum[a]	Average[a]	No. of Samples	Minimum[a]	Maximum[a]	Average[a]	No. of Samples	Minimum[a]	Maximum[a]	Average[a]	No. of Samples	Minimum[a]	Maximum[a]	Average[a]	Background[b]
Aluminum	28	3,190	20,300	9,174	34	2,310	25,000	14,542	49	5,450	48,000	21,711	3	8,650	10,200	9,177	--
Antimony	28	7	17	10	34	7	46	14	49	7	68	30	3	8	12	9	--
Arsenic	28	6	1,850	408	34	10	1,910	590	49	18	1,630	301	3	12	94	42	10
Barium	28	47	287	199	34	99	346	243	49	61	385	157	3	133	218	173	--
Beryllium	28	0	2	1	34	0	3	1	49	0	6	2	3	0	0	0	--
Cadmium	28	1	66	10	34	1	291	36	49	1	659	195	3	1	20	8	0.4
Calcium	28	1,690	198,000	37,318	34	2,350	192,000	28,740	49	423	186,000	47,294	3	15,400	169,000	79,100	--
Chromium	28	5	76	29	34	7	71	31	49	7	52	25	3	9	14	11	--
Cobalt	28	2	19	5	34	3	104	12	49	2	155	53	3	4	9	6	--
Copper	28	19	9,390	2,886	34	62	15,700	4,661	49	107	16,400	7,015	3	50	1,160	439	35
Iron	28	4,880	119,000	51,012	34	9,400	124,000	69,344	49	7,720	248,000	98,233	3	10,100	17,300	14,200	--
Lead	28	8	1,920	670	34	10	1,670	726	49	9	680	252	3	15	126	54	25
Magnesium	28	1,230	27,700	5,864	34	1,040	32,500	6,916	49	1,960	45,550	14,992	3	5,650	24,600	13,583	--
Manganese	28	120	9,320	2,717	34	229	14,300	2,563	49	211	14,100	6,405	3	203	1,410	628	250
Mercury	28	0	6	2	34	0	8	3	49	0	6	2	3	0	1	0	--
Nickel	28	3	50	10	34	3	119	17	49	5	211	60	3	7	10	9	--
Potassium	28	928	3,210	2,040	34	163	4,510	2,575	49	211	4,280	1,809	3	1,830	3,830	2,830	--
Selenium	28	0	11	3	34	0	12	4	49	1	44	14	3	3	4	3	--
Silver	28	1	26	11	34	1	22	12	49	1	35	8	3	1	2	2	--
Sodium	28	326	1,120	512	34	341	2,210	655	49	337	4,230	1,614	3	397	558	453	--
Thallium	28	0	1	1	34	0	3	1	49	0	4	2	3	1	1	1	--
Vanadium	28	6	63	33	34	15	90	46	49	4	39	26	3	15	25	19	--
Zinc	28	70	7,900	2,212	34	49	28,200	4,859	49	114	45,800	17,319	3	77	2,380	855	60
Cyanide	28	1	1	1	34	1	4	1	49	1	6	2	3	1	1	1	--
% Solids (wt. %)	28	37.4	92.1	64.8	34	13.6	87.9	55.1	49	9.1	6,706.0	172.0	3	53.8	75.6	67.8	--
Specific Conductance (umho/cm)	28	555.0	4,180.0	1,522.8	33	173.0	2,600.0	867.8	49	224.0	2,070.0	1,119.4	3	454.0	839.0	606.7	--
pE (mV)	28	-160.0	510.0	40.2	25	-240.0	100.0	-139.2	28	-210.0	110.0	-39.5	3	-220/0	-100.0	-163.3	--
pH (pH units)	28	2.3	8.3	5.6	34	4.1	7.6	6.5	48	6.2	9.5	8.2	3	7.8	8.3	8.0	--

[a]All units are mg/kg unless otherwise noted.
[b]From Moore, 1985.

Notes: 1. Undetected parameters are assumed to be at the detection limit.
2. Statistics are computed from the results for natural samples.

Source: CH2M HILL, 1989.

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below the required detection limits and the majority of analyses were below the instrument detection limits.[21]

Average concentrations of arsenic, cadmium, copper, lead, manganese, and zinc in Ponds 1, 2, and 3, and the wildlife ponds sediment are present above reported background levels (Table 2-5).

Four relatively distinct layers were encountered in sediments of Ponds 1, 2, and 3. The layers were identified primarily on the basis of color and texture, and were labeled Zones A through D. Zone A is the uppermost layer, zero to 5 feet thick, a relatively incompetent, highly saturated, jet-black, clayey-silt unit; Zone B is 2 to 7 feet thick, dark brown to reddish-orange, highly saturated, clayey silt; Zone C is a 3- to 7-foot-thick layer of dark gray, moderately saturated sandy silt with organic material present; and Zone D is the original pond bottom material, consisting of either peat or coarse sand and gravel units. Zones B and C have low permeabilities and thus tend to partially seal the bottoms of the ponds.

Figure 2-2 shows pond bottom sediment thicknesses within the ponds. Sediments are thicker on the eastern side of the ponds near the historic location of the Silver Bow Creek channel. Greatest thicknesses were encountered in Pond 3 (up to 22 feet) with lesser maximum thicknesses in Ponds 1 and 2 (up to 15 feet). Calculations indicate that the following approximate volumes of pond bottom material have accumulated in the Warm Springs Ponds: Pond 1--2.9 million in-place cubic yards; Pond 2--4.9 million cubic yards; and Pond 3--11.2 million cubic yards (Table 2-2).

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21 CH2M HILL, 1989.

Vertical distributions of average copper, zinc, cadmium, and arsenic concentrations within each pond were determined (Table 2-6). These data indicate decreases in copper, zinc, and cadmium from Pond 3 to Pond 2 and from Pond 2 to Pond 1. Arsenic concentrations are relatively higher in Ponds 1 and 2 compared to Pond 3.

Highest concentrations of copper, zinc, and cadmium were measured in Zone B in Ponds 2 and 3 and in Zone C in Pond 1 (Table 2-6). Arsenic exhibited highest concentrations in Zone C in all the ponds. Average concentrations of all four metals were lower throughout the pond system in Zone D, with the exception of copper in Pond 2.

Eleven pond bottom sediment samples were submitted for EP Toxicity metals analyses. Of the 11 samples analyzed, 5 were obtained from Pond 2, and 3 from Pond 3. Samples analyzed represented Zones A, B, and C in the sediment profile. Exceedances of the maximum concentration for cadmium (1,000 mg/l) were measured in two samples obtained from Zones B and C in Pond 3 and in one sample obtained from Zone B in Pond 2.

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SURFACE WATER

Physical Characterization

The surface water regime within the Warm Springs Ponds Operable Unit consists of the following components: Silver Bow Creek; Ponds 1, 2, 3, and the wildlife ponds; Opportunity Ponds discharges; and the Mill-Willow Bypass. Figure 2-5 schematically shows flow paths of surface water systems within the Operable Unit. Flow data for Silver Bow Creek and the Mill-Willow Bypass are presented in Table 2-7. Data on the three treatment ponds are summarized in Table 2-1.

Table 2-6
SUMMARY OF POND BOTTOM SEDIMENT DATA

	COPPER			ZINC		
	n	Average Concentration (mg/kg)	Range (mg/kg)	n	Average Concentration (mg/kg)	Range (mg/kg)
POND 3						
Zone A	4	6,300	2,400-8,500	7	20,400	2,100-37,300
Zone B	18	12,000	4,500-16,400	18	27,600	3,500-45,800
Zone C	14	5,100	1,100-11,900	14	10,900	700-31,600
Zone D	11	900	20-2,100	11	900	10-3,200
POND 2						
Zone A	5	3,600	1,200-5,600	5	3,900	400-7,200
Zone B	14	5,400	1,200-15,700	14	7,100	700-28,200
Zone C	10	4,100	60-6,800	10	3,700	80-7,400
Zone D	5	4,700	200-12,500	5	1,800	50-3,600
POND 1						
Zone A	4	700	500-900	4	600	200-1,200
Zone B	10	3,100	70-9,400	10	1,400	100-6,000
Zone C	9	4,500	90-8,500	9	4,100	300-6,800
Zone D	4	400	20-1,200	4	900	70-2,400

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Table 2-6
(Continued)

	ARSENIC			CADMIUM		
	n	Average Concentration (mg/kg)	Range (mg/kg)	n	Average Concentration (mg/kg)	Range (mg/kg)
POND 3						
Zone A	7	364	181-597	7	204	6-279
Zone B	18	323	164-835	18	365	11-615
Zone C	14	425	128-1,630	14	70	3-296
Zone D	11	171	21-706	11	11	1-16
POND 2						
Zone A	5	645	438-1,050	5	25	2-46
Zone B	14	568	284-966	14	60	2-291
Zone C	10	736	10-1,910	10	20	1-83
Zone D	5	301	29-633	5	9	1-28
POND 1						
Zone A	4	376	248-465	4	2.5	1-4
Zone B	10	324	120-671	10	10.6	1-66
Zone C	9	530	31-1,010	9	15	1-23
Zone D	4	41	6-94	4	6	1-20

Notes: 1. Data includes duplicate analyses.
2. n--number of values.

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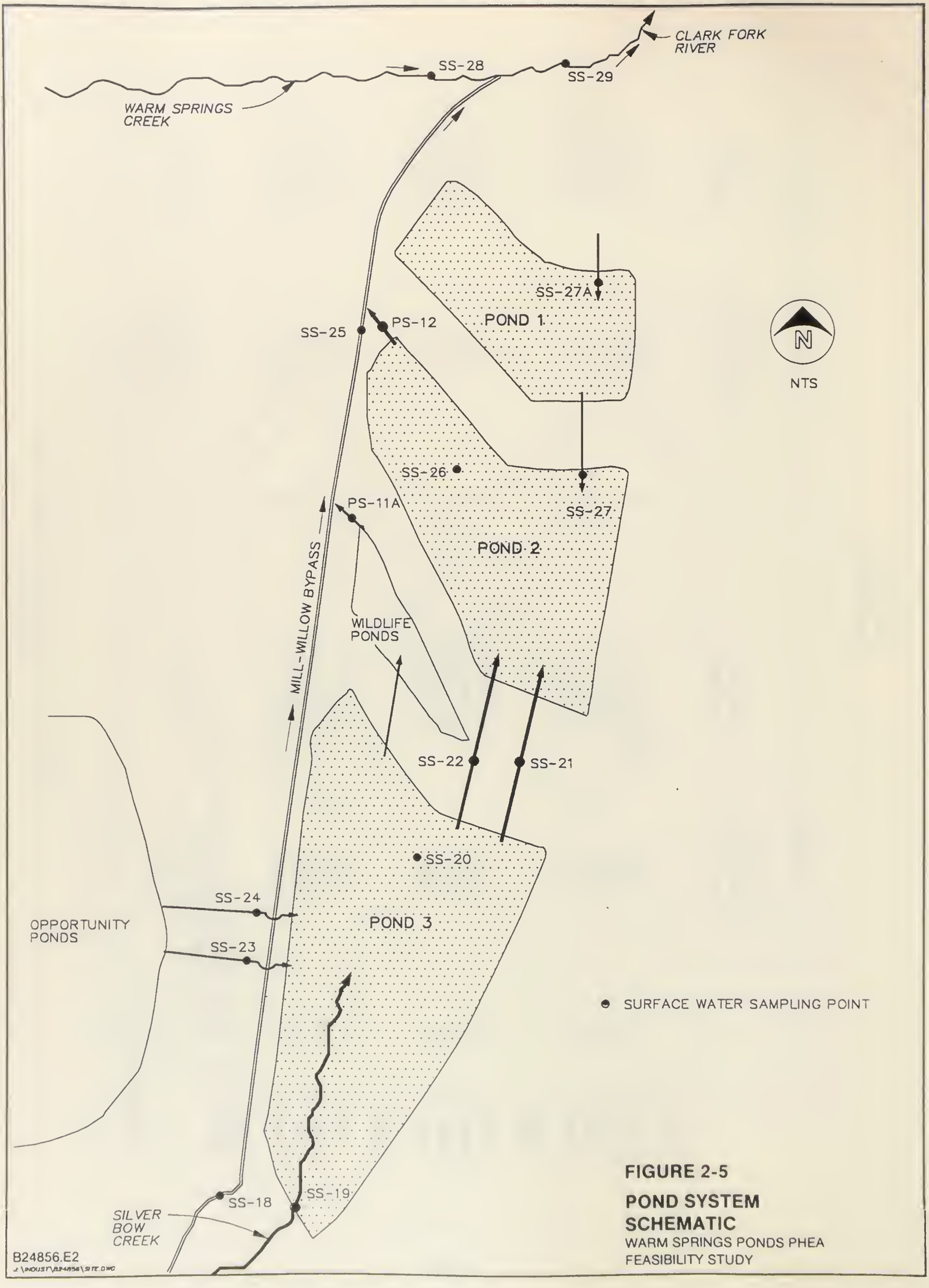

FIGURE 2-5

POND SYSTEM SCHEMATIC

WARM SPRINGS PONDS PHEA
FEASIBILITY STUDY

Table 2-7

SUMMARY OF STREAM DATA FOR THE
WARM SPRINGS PONDS OPERABLE UNIT

	Flow (cfs)[a]
Average Flow at Pond 3 Inlet	73
Average Flow in Mill Willow Bypass	27
Typical Combined (pond discharge plus bypass)	
o Average Low Flow (1972 to 1979)	50[b]
o Average High Flow (1972 to 1979)	110[b]
Silver Bow Creek 100-Year Flood Peak Flow	4,900
Silver Bow Creek Approximate PMF	146,000

[a]Data from Multitech, Phase I RI unless noted
[b]Data from USGS gaging station on Mill Willow Bypass

Silver Bow Creek enters Pond 3 from the south. Figure 2-6 shows the sampling and flow measurement sites used during the remedial investigation. Lime slurry is occasionally added during the winter months to Silver Bow Creek water above Pond 3 (SS-19, Figure 2-6) to raise the pH of the water to facilitate precipitation of metals. Two minor discharges from the Opportunity Ponds (SS-23 and SS-24, Figure 2-6) are also directed into Pond 3.

Pond 1 is currently used to collect seepage from Pond 2. This water is pumped back into Pond 2 periodically. Water seeping from below the Pond 1 berm is also pumped back into Pond 1 periodically. Seepage water pumped back into Pond 1 has historically been treated with lime slurry, although no observations of this practice were made during the remedial investigation.

Flows in Silver Bow Creek that exceed the capacity of the intake structure above Pond 3 (approximately 700 cfs) are routed directly into the Mill-Willow Bypass through a diversion channel. The diversion channel is equipped with an earthen plug, which fails when the flow rate of Silver Bow

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Creek exceeds approximately 700 cfs. The plug also fails at lower flows when debris that has collected on the pond system intake structure restricts flow through the structure. This mode of plug failure occurred at least twice during the remedial investigation study periods. During bypass events through the diversion channel, these volumes are not treated prior to entry into the Clark Fork River.

Flow data collected during the Phase I remedial investigation[22] indicate that the highest flows entering the site are generally associated with spring snow melt, which typically occurs March through June. Average instantaneous discharge measured in Silver Bow Creek above the Warm Springs Ponds (SS-19, Figure 2-6) during Phase I remedial investigation fieldwork (1984-1985) was 73 cfs. Maximum and minimum instantaneous discharges measured at SS-19 during the period 1984-1986 were 212 cfs in May 1986 and 28 cfs in July 1985. A maximum discharge of 288 cfs was measured at a continuously recording gauge at SS-19 during April 1986.

Outflows from the pond system averaged approximately 55 cfs at the Pond 2 discharge (PS-12) and almost 6 cfs at the discharge from the wildlife ponds (PS-11A) during the Phase I remedial investigation (Figure 2-6). Maximum and minimum instantaneous discharges measured at these two sites during the same time period were 186 cfs and 10 cfs at PS-12, and 8.2 cfs and 3.2 cfs at PS-11A.

Maximum, minimum, and average discharges measured at the head of the Mill-Willow Bypass (SS-18, Figure 2-6) during the remedial investigation were 87 cfs, 3.3 cfs, and 27 cfs, respectively. Flows measured at SS-25 (Figure 2-6) near the mouth of the bypass but above its confluence with Pond 2

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22 MultiTech, 1987.

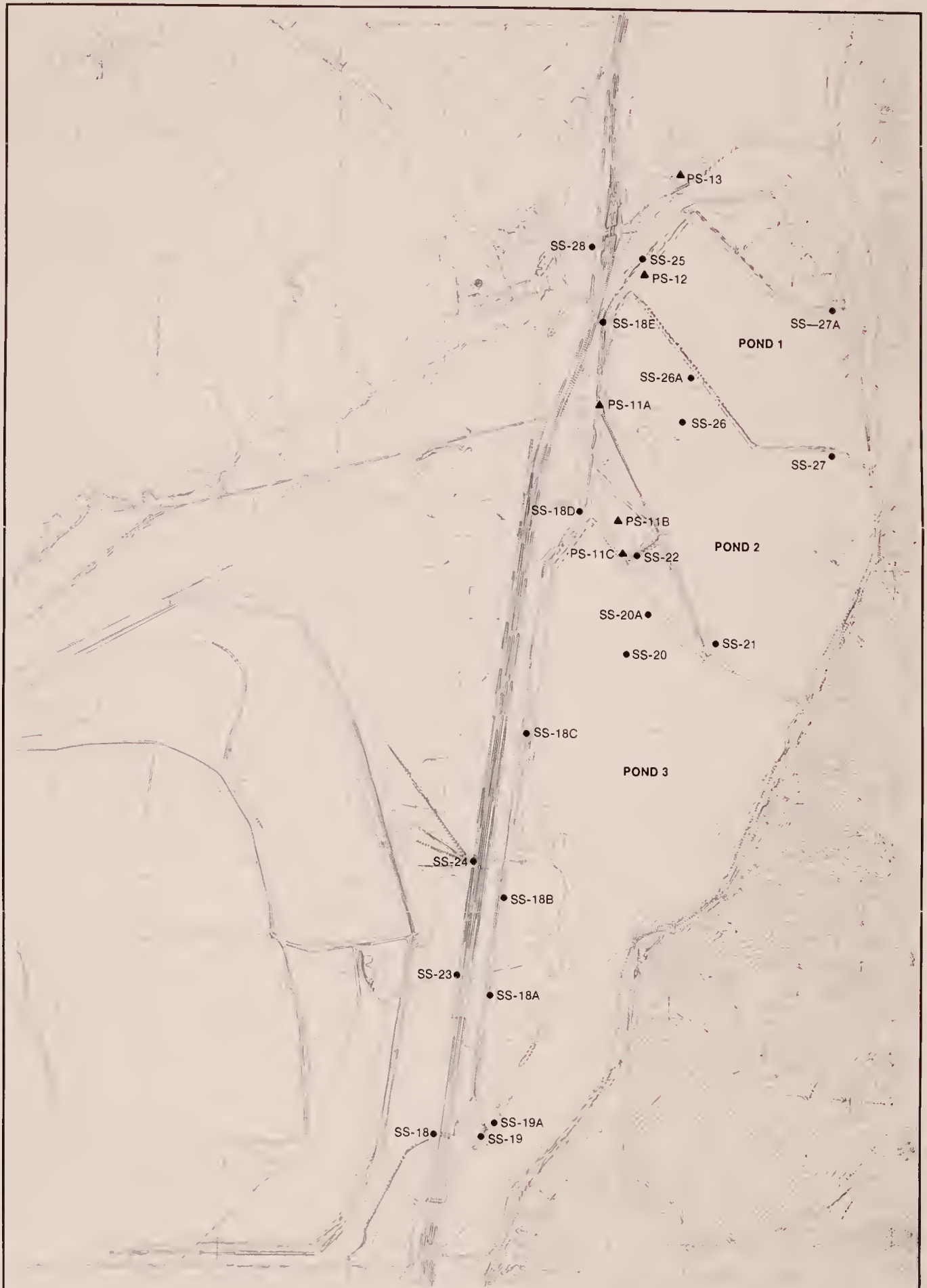

FIGURE 2-6

SURFACE WATER SAMPLING LOCATIONS
WARM SPRINGS PONDS
FEASIBILITY STUDY

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discharge were relatively higher than those measured at SS-18, even after subtracting input to the bypass from the wildlife ponds. This indicates groundwater inflow to the bypass is measurable in this reach. Maximum, minimum, and average flows determined for Sampling Station SS-25 during the course of the remedial investigation were 91 cfs, 13 cfs, and 33 cfs, respectively.

Seepage runs (synoptic flow measurements) along the Mill-Willow Bypass completed during base flow conditions in the summer and fall of 1985 indicated the bypass loses water in its upper reach above Pond 3 and gains approximately 2.5 cfs in the reach from the upper end of Pond 3 to the Pond 2 discharge. The source of increased flow in the middle and lower reaches of the bypass channel is most likely groundwater inflow from the Warm Springs Ponds and Opportunity Ponds area.

A separate seepage run was conducted on the Mill-Willow Bypass during the Phase II remedial investigation in July 1988 in the reach from the north Opportunity Ponds discharge (SS-24, Figure 2-6) to the Pond 2 discharge. At the time, AMC was diverting the entire flow of the bypass into Pond 3 via the north Opportunity Ponds discharge ditch. Water entering the bypass below this point was entirely groundwater inflow. Measurements of this flow verified that the volume of groundwater entering the bypass over this reach is approximately 2.5 cfs.

Quality Characterization

Surface water quality data consist primarily of analytical and flow data collected during the Phase I remedial investigation (1984-1985), limited inflow data collected during 1986, and diurnal sampling data collected from 8 to 10 sites

during the Phase II remedial investigation (1987-1988). Surface water sampling sites are shown on Figure 2-6. Tables 2-8 and 2-9 summarize surface water analytical data collected at sites in and adjacent to the Warm Springs Ponds during the Phase I and Phase II remedial investigations, respectively.

A mass balance study of the Warm Springs Ponds conducted as part of the Phase I remedial investigation showed that metals are being removed by the current treatment system. Inflow loads of total copper and total zinc were reduced by over 90 percent by the time the water left the pond system during summer months. The mass balance study was not conducted with data from the winter period, but samples of the inflow and outflow taken during the winter showed reductions in the concentrations of total zinc and total copper of 50 to 70 percent.

The pH varies seasonally in the pond system, from a low of about 7.0 standard units in the winter to a high of near 10.0 standard units in the summer. The effect of this variation on metals precipitation is pronounced. Decreases in metal concentrations are evident beginning in May. Figure 2-7 illustrates this phenomenon for zinc.

The ponds function to reduce dissolved metals loads in the outflow by allowing metal precipitates to settle out of solution. Two changes occur during winter months that affect the ponds' operation. The pH in the ponds decreases and ice forms over the ponds reducing the capacity of the ponds. The reduced pH inhibits the formation of many of the metal hydroxides. The decreased pond capacity increases the velocity of the water flowing through the system, which can reduce the amount of the precipitates that will settle out of suspension.

Table 2-8
SUMMARY OF SURFACE WATER QUALITY DATA FROM PHASE I RI

Parameter[a]	Sample Station[b] PS-11A Average	PS-11A Maximum	PS-11A Minimum	PS-12 Average	PS-12 Maximum	PS-12 Minimum	SS-18 Average	SS-18 Maximum	SS-18 Minimum	SS-19 Average	SS-19 Maximum	SS-19 Minimum	SS-20 Average	SS-20 Maximum	SS-20 Minimum
Flow (cfs)	5.8	8.2	3.2	55.4	134	10.0	26.6	87.3	3.3	73	112	28	NA	NA	NA
Temperature (^{o}C)	10	21	2.0	11	24	0.5	4.90	13	0.5	14.5	24	6	8.2	22	0.0
pH (s.u.)	7.8	8.6	6.6	8.4	9.7	7.2	7.4	8.0	6.9	84	9.5	7.1	8.3	9.6	6.8
SC (umhos/cm @ 25^{o}C)	534	773	443	479	641	385	283	398	102	343	702	287	451	588	287
TSS	1	5	[d]	6	17	[d]	4	10	[c]	15	40	8	8	29	[d]
SO_4	134	185	103	134	168	102	53	80	13	66	81	49	119	190	54
Nitrate	1.80	6.8	[d]	2.15	6.6	[d]	1.38	2.80	[c]	3.13	5.2	1.2	2.31	4.8	[d]
Alkalinity	116	150	82	82	129	40	85	125	33	92	106	81	94	125	60
Hardness	196	284	30	177	264	79	129	218	51	148	235	107	170	254	79
As (T)	0.013	0.023	0.0062	0.011	0.018	0.0015	0.026	0.105	[c]	0.019	0.048	0.0014	0.012	0.023	[d]
Cd (T)	[c]	[c]	[d]	0.002	0.0014	[d]	0.0001	0.0012	[c]	0.0012	0.0021	0.0004	0.0009	0.0027	[d]
Cu (T)	0.023	0.072	[d]	0.050	0.139	[d]	0.031	0.092	[c]	0.170	0.262	0.094	0.083	0.202	0.014
Cu (D)	0.003	0.023	[d]	0.006	0.051	[d]	0.003	0.031	[c]	0.041	0.059	[d]	0.007	0.076	[d]
Pb (T)	0.001	0.0072	[d]	0.004	0.017	[d]	0.001	0.0076	[c]	0.012	0.028	0.0018	0.006	0.015	[d]
Fe (T)	0.087	0.179	0.025	0.443	1.43	0.0107	0.259	0.470	0.170	0.979	2.28	0.435	0.670	2.06	0.129
Fe (D)	0.006	0.055	[d]	0.023	0.215	[d]	0.058	0.446	[c]	0.048	0.107	0.016	0.013	0.047	[d]
Zn (T)	0.035	0.202	[d]	0.151	0.431	0.024	0.045	0.377	0.010	0.415	0.642	0.240	0.268	0.620	0.036
Zn (D)	0.029	0.186	[d]	0.098	0.215	[d]	0.028	0.345	[c]	0.163	0.321	0.038	0.148	0.502	[d]

[a]Values in mg/l unless otherwise noted; (T) is total; (D) is dissolved.
[b]Sample station locations shown on Figure 2-6.
PS-11A: Wildlife ponds discharge
PS-12: Pond 2 discharge
SS-18: Head of Mill-Willow Bypass
SS-19: Silver Bow Creek below upper pH shack
SS-20: Pond 3 (off shore)
[c]Parameter not analyzed.
[d]Minimum below detection.

Table 2-8
(continued)

Parameter[a]	Sample Station[b] SS-21 Average	SS-21 Maximum	SS-21 Minimum	SS-22 Average	SS-22 Maximum	SS-22 Minimum	SS-23 Average	SS-23 Maximum	SS-23 Minimum	SS-24 Average	SS-24 Maximum	SS-24 Minimum
Flow (cfs)	24.2	61.8	5.2	28.3	74.8	4.5	1.3	2.3	0.15	0.97	1.8	0.36
Temperature (°C)	11	26	1.5	11	22	4	8.8	19	0.5	9.7	23.5	0.0
pH (s.u.)	8.3	9.4	7.3	8.4	9.3	7.2	6.9	7.8	6.5	7.4	7.8	6.8
SC (umhos/cm @ 25°C)	696	696	358	450	616	360	2203	3050	1870	2461	2800	2290
TSS	6	36	[d]	5	18	[d]	15	31	[c]	6	17	[c]
SO_4	110	140	98	114	177	91	1260	1490	1000	1401	1580	1160
Nitrate	2.74	9.8	[d]	2.23	6.3	[d]	1.97	6.0	0.67	2.10	5.0	[c]
Alkalinity	92	127	64	92	143	62	112	130	91	218	268	158
Hardness	173	236	75	173	248	62	1322	1510	1140	1515	1870	614
As (T)	0.013	0.026	0.0014	0.012	0.025	[d]	0.010	0.025	[c]	0.004	0.019	[c]
Cd (T)	0.0008	0.0029	0.0004	0.00007	0.0018	[d]	[c]	0.0003	[c]	0.0001	0.0006	[c]
Cu (T)	0.074	0.218	[d]	0.064	0.183	0.017	0.027	0.065	[c]	0.31	0.100	[c]
Cu (D)	0.007	0.045	[d]	0.006	0.033	[d]	0.004	0.054	[c]	0.001	0.021	[c]
Pb (T)	0.005	0.018	[d]	0.004	0.020	[d]	0.011	0.129	[c]	0.016	0.192	[c]
Fe (T)	0.681	2.14	0.172	0.535	1.84	0.104	6.92	24.2	0.246	0.579	1.46	0.229
Fe (D)	0.033	0.283	[d]	0.030	0.324	[d]	5.02	21.4	[c]	0.377	3.00	[c]
Zn (T)	0.266	0.811	0.049	0.288	0.524	0.27	0.288	0.632	0.063	0.198	1.68	0.035
Zn (D)	0.124	0.421	[c]	0.120	0.415	[d]	0.280	0.642	0.054	0.054	0.146	0.019

[a] Values in mg/l unless otherwise noted; (T) is total; (D) is dissolved.
[b] Sample station locations shown on Figure 2-6.
SS-21: East decant from Pond 3
SS-22: West decant from Pond 3
SS-23: South Opportunity Ponds discharge
SS-24: North Opportunity Ponds discharge
[c] Parameter not analyzed.
[d] Minimum below detection.

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Table 2-8
(continued)

Parameter[a]	Sample Station[b] SS-25 Average	SS-25 Maximum	SS-25 Minimum	SS-26 Average	SS-26 Maximum	SS-26 Minimum	SS-27 Average	SS-27 Maximum	SS-27 Minimum	SS-28 Average	SS-28 Maximum	SS-28 Minimum
Flow (cfs)	32.7	91	12.9	NA	NA	NA	12.1	2.2	0.40	0.92	1.8	1
Temperature (^{o}C)	8.9	24.0	1.0	9.0	23.0	0.0	10.9	25	1.0	13.9	23	6.0
pH (s.u.)	7.8	8.5	7.1	7.5	10.1	6.8	7.4	8.1	6.5	6.6	6.9	6.3
SC (umhos/cm @ 25^{o}C)	523	785	203	491	596	416	1489	1740	1130	1919	2160	1420
TSS	4	9	c	14	45	c	12	19	2	65	85	47
SO_4	164	260	46	132	192	114	741	998	425	991	1160	609
Nitrate	1.56	3.70	c	2.17	4.30	c	2.00	4.20	0.48	1.45	3.20	0.60
Alkalinity	100	129	45	93	137	43	132	192	95	109	118	96
Hardness	229	344	88	189	268	72	779	988	499	1026	1180	675
As (T)	0.022	0.120	c	0.015	0.034	c	0.004	0.012	c	0.077	0.128	0.0017
Cd (T)	0.0001	0.0012	c	0.0024	0.012	c	c	c	c	c	c	c
Cu (T)	0.037	0.100	c	0.143	0.419	0.010	0.014	0.055	c	0.087	0.190	0.025
Cu (D)	0.003	0.022	c	0.004	0.019	c	c	c	c	0.035	0.075	c
Pb (T)	0.002	0.0076	c	0.011	0.033	c	0.001	0.0086	c	c	c	c
Fe (T)	0.478	0.690	0.213	1.57	5.80	0.067	2.32	7.99	0.047	35.7	54.2	13.5
Fe (D)	0.046	0.190	c	0.024	0.139	c	1.16	5.34	c	28.5	37.5	6.49
Zn (T)	0.072	0.304	0.026	0.386	1.41	0.010	0.056	0.135	0.016	0.433	0.547	0.243
Zn (D)	0.050	0.244	c	0.105	0.374	c	0.105	0.127	c	0.449	0.567	0.240

[a]Values in mg/l unless otherwise noted; (T) is total; (D) is dissolved.
[b]Sample station locations shown on Figure 2-6.
SS-25: Mill-Willow Bypass above Pond 2 discharge
SS-26: Pond 2 (off shore)
SS-23: South Opportunity Ponds discharge
SS-27: Pumpback from Pond 1 to Pond 2
SS-27A: Pumpback discharge from below Pond 1)
[c]Parameter not analyzed.
[d]Minimum below detection.

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Table 2-9
SUMMARY OF SURFACE WATER DATA
WARM SPRINGS PONDS OU PHASE II REMEDIAL INVESTIGATION

SAMPLE SITE NUMBER: PS-11A; WILDLIFE PONDS DISCHARGE

Parameter	September 1987			January 1988			April 1988			July 1988		
	n	Range	Average	n	Range	Average	n	Range	Average	n	Range	Average
Potassium (ug/l)	11	4700-7100	5909	14	6850-7770	7233	12	4300-4750	4567	12	4700-5200	4958
Sodium (ug/l)	11	13800-17800	17109	14	23600-27600	25400	12	18600-19900	19250	12	17800-19500	18842
Sulfate (mg/l)	12	109-119	113	12	110-140	123	12	114-130	123	12	112-121	118
Chloride (mg/l)	12	8-9	8.5	14	12-13	12.4	12	10.4-10.9	10.6	12	8.4-11.0	9.6
Alkalinity (mg/l)	12	114-118	116	14	117-134	125.5	12	91.4-99.5	95.1	12	102-113	107
Chlorophyll "a" (mg/ml)	12	1-2	1.5	14	0.1-0.7	0.4	12	11.4-18.3	15.0	11	1.0-2.1	1.4
Phytoplankton (counts/ml)	12	1260-2050	1628	14	410-2220	1616	12	6240-11900	9641	12	312-1750	795
pH (S.U.)	12	7.6-8.1	7.8	14	7.4-7.9	7.7	12	7.7-8.5	8.2	12	7.8-8.9	8.5
DO (mg/l)	12	4.0-7.4	6.4	14	9.2-12.6	10.2	12	6.3-8.4	7.4	12	5.0-9.2	7.3
SC (umhos/cm)	12	461-494	482	14	421-525	500	12	348-462	440	12	429-455	445
Temperature (Co)	12	9-16	12.6	14	0.5-3.0	1.7	12	9.5-12.5	11.3	12	15-20.5	17.5
Flow (cfs)	2	3.2-3.8	3.5	4	7.0-7.7	7.4	1	7.4-7.4	7.4	2	6.7-7.2	7.0
Hardness (mg/l)	12	144-213	191	14	252-282	266	12	184-207	193	12	183-195	190
Magnesium (ug/l)	12	677-12700	10800	14	15400-17600	16590	12	11600-12800	12183	12	12800-13700	13267
Calcium (ug/l)	12	45600-64300	58860	14	74100-84300	78700	12	54600-61600	57350	12	52200-55800	54058
Aluminum (ug/l)												
Total	12	41-264	60	14	90-90	90	12	54-130	91	12	100-200	192
Acid Soluble	12	41-41	41	14	90-90	90	12	54-70	56	12	200-200	200
Dissolved	12	41-315	74	14	90-90	90	12	54-54	54	12	200-211	201
Arsenic (ug/l)												
Total	12	17-82	27	14	3-11	9.3	12	9.8-25.0	13.1	12	13-16	14.3
Acid Soluble	12	15-21	18	14	8.8-12	10.2	12	5.0-10.2	7.4	12	15-17	15.7
Dissolved	12	11-18	16	14	9.8-11	10.5	12	6.1-10.7	9.8	12	13-16	14.3
Cadmium (ug/l)												
Total	12	0.1-2.3	1.0	14	0.5-2.2	1.2	12	0.4-1.3	0.9	12	0.3-0.7	0.5
Acid Soluble	12	0.1-8.0	2.8	14	0.8-2.1	1.3	12	0.1-1.9	1.1	12	0.4-1.3	0.7
Dissolved	12	0.1-3.3	1.6	14	0.1-3.4	1.8	12	1.3-6.7	3.0	12	0.7-2.7	1.4
Copper (ug/l)												
Total	12	6.0-6.0	6.0	14	9.2-13	10.8	12	10.4-16.3	12.1	12	3.0-3.8	3.3
Acid Soluble	12	6.0-9.0	6.3	14	8.4-10	9.4	12	3.0-7.2	5.7	12	3.6-4.1	3.8
Dissolved	12	6.0-9.0	6.8	14	3.2-7.6	4.1	12	4.2-6.8	5.3	12	3.0-3.0	3.0
Iron (ug/l)												
Total	12	21-44	25.5	14	84-107	91.9	12	62.4-90.0	76.4	12	43-67	55.0
Acid Soluble	12	21-21	21.0	14	66-85	72.8	12	45.1-180.0	86.3	12	24-101	66.7
Dissolved	12	21-68	25.3	14	15-94	20.8	12	27.0-192.0	60.0	12	10.0-18.0	12.5
Lead (ug/l)												
Total	11	1.0-1.4	1.0	14	1-5.9	1.4	12	1.0-2.0	1.1	12	1.0-1.0	1.0
Acid Soluble	12	1.0-1.4	1.0	14	1-2.9	1.2	12	1.0-7.5	2.3	12	1.0-1.0	1.0
Dissolved	12	1.0-7.0	1.5	14	1-1.7	1.1	12	1.0-1.0	1.0	12	1.0-1.0	1.0
Manganese (ug/l)												
Total	12	150-735	582	14	453-548	493	12	611-1050	794	12	580-1192	787
Acid Soluble	12	490-682	593	14	496-575	537	12	594-963	753	12	650-1088	847
Dissolved	12	387-608	498	14	512-560	538	12	475-910	654	12	620-1257	834
Zinc (ug/l)												
Total	12	7.0-110	24.1	14	47-122	60.0	12	21-69	27	11	6.0-34.0	12.5
Acid Soluble	12	7.0-48	18.3	14	50-76	57.3	12	18-144	35	12	7.0-190	74.9
Dissolved	10	7.0-18.0	9.5	14	36-50	42.8	12	11-17	12	11	5.0-80.0	12.3

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Table 2-9
(Continued)

SAMPLE SITE: SS-19; SILVER BOW CREEK ABOVE PONDS

Parameter	September 1987 n	Range	Average	January 1988 n	Range	Average	April 1988 n	Range	Average	July 1988 n	Range	Average
Potassium (ug/l)	12	2900-7300	4516	12	4310-5470	5088	12	4020-5180	4591	12	3660-5470	4502
Sodium (ug/l)	12	15100-19800	17616	12	24500-29600	28158	12	14700-16200	15708	12	23000-26200	24575
Sulfate (mg/l)	12	52-78	68	12	72-96	82	12	67-78	71	12	82-92	88
Chloride (mg/l)	12	8-11	9.5	12	12-15	13.8	12	8-10	9.2	12	13-14	13.4
Alkalinity (mg/l)	12	102-110	107	12	111-116	114	12	67-89	81	12	94-112	106
Chlorophyll "a" (mg/ml)	12	8-38	19.8	12	1.6-3.2	2.5	12	17-50	27.5	12	12-28	18
Phytoplankton (counts/ml)	12	1360-13340	6825	12	922-4110	2564	12	6850-30000	14331	12	1870-4340	2767
pH (S.U.)	12	7.8-8.4	8.1	12	7.0-7.7	7.2	12	7.3-7.7	7.5	12	7.8-9.5	8.8
DO (mg/l)	12	10.0-13.5	11.4	12	6.9-9.5	8.0	11	5.2-8.0	7.2	12	7.8-10.1	8.9
SC (umhos/cm)	12	331.448	365	12	407-463	434	12	288-394	344	12	383-430	411
Temperature (Co)	12	5-14	10.0	12	0-2	0.8	12	7-12	9.3	12	12-18.5	15.2
Flow (cfs)	4	48.4-49.2	48.8	2	24.8-27.6	26.2	2	78.6-99.3	89.0	2	30.4-31.6	31.0
Hardness (mg/l)	12	147-172	158	12	174-190	183	12	128-137	132	12	145.7-174.1	161.3
Magnesium (ug/l)	11	9600-10800	10054	12	11300-12300	11758	12	7500-8200	7844	12	10100-12200	11108
Calcium (ug/l)	11	43700-51100	46936	12	50900-55900	53767	12	38800-41500	40133	12	41700-49700	46292
Aluminum (ug/l)												
Total	12	181-997	386	12	90-251	118	12	600-1440	917	12	73.0-312	198.4
Acid Soluble	12	50-217	130	12	90-125	95	12	109-607	392	12	73.0-128.0	80.3
Dissolved	11	41-52	43	12	90-90	90	12	71-94	80	12	73.0-184.0	95.0
Arsenic (ug/l)												
Total	11	14-23	18.1	12	11-14	13.1	12	22-41	29.5	12	25.0-29.0	26.9
Acid Soluble	12	0.2-21	14.5	12	12-14	13.1	12	6-35	24.3	12	23.0-29.0	26.8
Dissolved	12	2.2-12	8.4	12	10-12	11.5	12	6-15	10.9	12	18.0-22.0	20.6
Cadmium (ug/l)												
Total	12	0.2-5.3	2.9	12	4.2-5.6	4.9	12	3.8-8.6	5.1	12	1.5-3.0	2.0
Acid Soluble	12	0.1-10	5.2	12	3.0-5.3	3.8	12	0.7-5.8	3.6	12	1.3-3.0	1.9
Dissolved	12	1.1-7.8	4.7	12	3.5-6.9	4.8	4	4.2-4.8	4.5	12	1.4-4.4	2.7
Copper (ug/l)												
Total	12	189-501	311	12	134-147	141	12	328-604	440	12	109.0-137.0	124
Acid Soluble	12	191-457	320	12	130-150	144	12	29-596	383	12	116.0-144.0	132
Dissolved	11	37-69	52	12	56-76	69	12	76-101	86	12	38.0-54.0	46.9
Iron (ug/l)												
Total	12	643-1600	1030	12	454-566	494	12	1720-2780	2278	12	556-718	635
Acid Soluble	12	469-1000	717	12	405-469	435	12	202-2120	1448	12	456-682	575
Dissolved	11	21-104	36	12	15-34	17	12	66-120	97	12	26.0-80.0	41.3
Lead (ug/l)												
Total	12	1.0-25.0	12.5	12	5.3-12.0	8.3	12	14.3-75.3	45.7	12	5.2-11.0	7.7
Acid Soluble	12	4.4-16.0	9.2	12	5.4-7.3	6.1	12	2.8-36.5	23.3	12	4.2-8.2	5.8
Dissolved	12	1.0-1.0	1.0	12	1.0-1.0	1.0	11	1.0-3.3	2.0	12	1.0-1.0	1.0
Manganese (ug/l)												
Total	12	625-853	719	12	591-658	642	12	780-1230	907	12	333-683	479
Acid Soluble	12	619-739	672	12	640-692	670	12	205-1150	837	12	307-703	471
Dissolved	11	199-699	528	12	605-704	674	12	701-1070	788	12	162-597	350
Zinc (ug/l)												
Total	12	637-1100	877	12	726-853	812	12	835-1300	968	12	272-536	346
Acid Soluble	12	722-1200	919	12	809-864	842	12	70-1230	855	12	261-451	347
Dissolved	11	86-736	345	12	700-816	770	12	366-688	460	12	23.0-112	49.2

Notes: (1) Statistics are computed with data for natural samples.
(2) For statistical purposes, values reported as below detection limits are treated as being at the reported detection limit.
(3) N/A--parameter not applicable.

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Table 2-9
(Continued)

SAMPLE SITE: SS-20; POND 3

Parameter	September 1987 n	Range	Average	January 1988 n	Range	Average	April 1988 n	Range	Average	July 1988 n	Range	Average
Potassium (ug/l)	12	3200-8400	4946	12	6450-7600	6926	12	2640-3830	3119	12	3660-4810	4205
Sodium (ug/l)	12	20000-27300	21060	12	23500-26500	25333	12	17600-20200	18900	12	19400-21700	20367
Sulfate (mg/l)	12	107-119	114	12	100-130	111	12	104-120	113	12	98-116	107
Chloride (mg/l)	12	11-11	11	12	8.5-14.0	13.8	12	9.6-10.7	10.2	12	8.4-10.0	9.3
Alkalinity (mg/l)	12	73-73	73.0	12	118-122	120	12	60.9-69.0	67.0	11	77-83	79.9
Chlorophyll "a" (mg/ml)	12	1-11	8.2	12	0.3-1.0	0.5	12	34.2-45.2	40.0	12	1.7-3.2	2.7
Phytoplankton (counts/ml)	12	2650-9190	5992	12	372-1550	926	12	5700-9070	7132	11	145-363	263
pH (S.U.)	12	8.6-9.4	9.0	12	7.9-8.2	8.0	12	8.8-9.3	9.2	12	8.2-8.3	8.2
DO (mg/l)	11	7.2-10.2	9.5	12	11.1-17.0	15.4	12	10.6-11.4	11.0	10	6.0-7.9	415
SC (umhos/cm)	12	363-410	388	12	472-502	490	12	374-393	386	12	407-425	19.9
Temperature (Co)	12	10-15	12.3	12	2.0-4.0	2.4	12	12-14	13.0	12	18-23	
Flow (cfs)	N/A			N/A			N/A			N/A		
Hardness (mg/l)	12	154-213	163	12	214-236	228	12	146-165	156	12	155.5-174.0	163.5
Magnesium (ug/l)	12	12300-16900	13050	12	14100-15600	14983	12	10300-11600	11067	12	12300-13500	12692
Calcium (ug/l)	12	41100-57300	43925	12	62600-69000	66525	12	41600-46800	44392	12	42000-47400	44533
Aluminum (ug/l)												
Total	12	42-633	214	12	90-90	90	12	115-227	146	12	73.0-229	110.8
Acid Soluble	12	41-41	41	12	90-90	90	12	62-191	133	12	73.0-353	184.8
Dissolved	12	41-62	44	12	90-90	90	12	54-54	54	12	73.0-168	92.8
Arsenic (ug/l)												
Total	12	7.2-12.0	8.8	12	7.4-9.1	8.7	12	5.8-11.9	9.9	12	9.8-12.0	10.3
Acid Soluble	12	2.2-11.0	8.0	12	5.2-8.6	7.4	12	9.0-15.2	12.3	12	8.5-11.0	9.9
Dissolved	12	6.2-10.0	7.9	12	6.8-8.7	7.5	12	5.5-11.4	8.3	12	10.0-10.0	10.0
Cadmium (ug/l)												
Total	12	0.1-2.6	1.8	12	1.1-2.2	1.5	12	1.1-3.2	1.7	12	0.7-2.6	1.3
Acid Soluble	12	0.2-6.0	1.5	12	1.0-2.7	1.6	12	1.2-5.7	2.8	12	0.5-2.1	1.4
Dissolved	12	1.0-5.2	2.7	12	1.4-4.8	2.9	12	2.6-6.8	4.4	11	1.0-4.4	2.3
Copper (ug/l)												
Total	12	14-33	23.1	12	21-32	24.7	12	19-45	25.9	12	18.0-39.0	28.8
Acid Soluble	12	13-26	16.0	12	16-25	22.8	12	12-49	33.3	12	18.0-36.0	27.8
Dissolved	12	6-17	9.5	12	14-19	16.1	12	8-41	14.1	12	4.4-9.5	5.7
Iron (ug/l)												
Total	12	113-308	217	12	134-155	145	12	371-1300	580	11	174-588	397.3
Acid Soluble	12	41-224	124	12	120-136	129	12	160-999	416	12	168-490	356.9
Dissolved	12	21-225	48	12	15-15	15	12	27-462	128	12	15.0-19.0	15.5
Lead (ug/l)												
Total	12	1.0-5.0	4.7	12	1.1-5.4	2.2	12	1.0-3.7	2.1	12	1.0-1.0	1.0
Acid Soluble	12	1.0-1.1	1.0	12	1.0-1.8	1.1	12	1.0-1.8	1.3	12	1.0-4.6	1.9
Dissolved	12	1.0-1.0	1.0	12	1.0-1.0	1.0	12	1.0-1.0	1.0	12	1.0-1.0	1.0
Manganese (ug/l)												
Total	12	46-109	71	12	75-83	77	12	150-205	167	12	200-333	266
Acid Soluble	12	34-71	51	12	79-97	86	12	87-188	164	12	224-303	266
Dissolved	12	14-22	17	12	70-78	73	12	35-78	47	12	162-236	204
Zinc (ug/l)												
Total	12	47-147	74	12	127-241	159	12	105-204	129	12	55.0-159	113.8
Acid Soluble	12	35-114	62	12	147-248	177	12	87-192	119	12	76.0-173	126.6
Dissolved	12	7-68	17	12	105-293	130	12	12-65	27	12	11.0-25.0	16.7

Notes: (1) Statistics are computed with data for natural samples.
(2) For statistical purposes, values reported as below detection limits are treated as being at the reported detection limit.
(3) N/A--parameter not applicable.

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Table 2-9
(Continued)

SAMPLE SITE: SS-22; DISCHARGE FROM POND 3

Parameter	September 1987 n	September 1987 Range	September 1987 Average	January 1988 n	January 1988 Range	January 1988 Average	April 1988 n	April 1988 Range	April 1988 Average	July 1988 n	July 1988 Range	July 1988 Average
Potassium (ug/l)	12	3500-6100	4692	12	7130-7620	7350	12	2050-4810	3348	12	3400-4500	3825
Sodium (ug/l)	12	17800-21000	19950	12	24900-27700	26200	12	16400-19500	18150	12	16100-21100	18892
Sulfate (mg/l)	12	109-121	116	12	110-150	125	12	110-119	114	12	114-141	118
Chloride (mg/l)	12	11-11	11.0	12	13-14	13.7	12	10-11	10.3	12	8.7-10.0	9.2
Alkalinity (mg/l)	12	69-73	72.5	12	118-122	120	12	67-73	69.7	12	80-86	82.1
Chlorophyll "a" (mg/ml)	11	3-13	10.1	12	0.5-2.9	0.9	12	35-45	40.6	12	1.4-4.6	3.1
Phytoplankton (counts/ml)	12	5310-8330	6403	12	758-2270	1343	12	5790-8880	7390	12	182-486	313
pH (S.U.)	12	8.2-9.2	9.0	12	7.6-8.1	8.0	12	9.1-9.3	9.2	12	7.8-8.2	8.1
DO (mg/l)	12	7.1-9.3	8.9	12	11.8-17.7	12.7	12	8.6-9.1	8.8	12	5.8-7.3	6.5
SC (umhos/cm)	12	340-416	394	12	479-507	495	12	384-424	404	12	385-426	407
Temperature (Co)	12	9-15	11.8	12	1.5-2.0	2.0	12	12-15	13.1	12	19-20	19.7
Flow (cfs)	2	22.9-23.8	23.4	2	12.6-14.3	13.5	1	57.2-57.2	57.2	1	6.9-6.9	6.9
Hardness (mg/l)	12	149-162	156	12	229-248	240	12	150-191	162	12	164.8-175.4	169.5
Magnesium (ug/l)	12	11600-12900	12158	12	14400-16100	15308	12	10600-12900	11292	12	12600-13800	13133
Calcium (ug/l)	12	40400-43600	42350	12	67900-72600	70708	12	42800-55400	46375	12	45200-47500	46242
Aluminum (ug/l)												
Total	12	44-105	83	12	90-90	90	12	81-135	112	12	96.0-200.0	159.9
Acid Soluble	12	41-62	46	12	90-90	90	12	79-206	109	12	140.0-393.0	238.3
Dissolved	12	41-90	57	12	90-90	90	12	54-159	86	12	73.0-200.0	149.4
Arsenic (ug/l)												
Total	12	2.2-12.0	8.6	12	7.4-9.0	8.4	12	5.0-17.4	11.6	12	10.0-11.0	10.2
Acid Soluble	12	2.2-10.0	5.9	12	6.6-8.8	7.8	12	7.2-18.3	11.7	12	10.0-12.0	10.3
Dissolved	12	2.2-7.4	5.5	12	7.8-9.5	8.6	12	5.8-12.5	8.8	12	10.0-10.0	10.0
Cadmium (ug/l)												
Total	12	0.1-2.5	1.4	12	1.3-5.6	3.0	12	1.1-3.4	1.8	12	1.5-5.0	2.3
Acid Soluble	12	0.2-6.0	1.2	12	0.9-6.8	2.8	11	1.0-1.9	1.3	12	0.7-5.0	2.5
Dissolved	12	1.1-16.0	4.2	12	1.5-11.0	5.0	12	1.4-10.9	4.0	12	0.9-7.6	4.4
Copper (ug/l)												
Total	12	15-33	23.1	12	22-29	25.8	12	12-40	27	12	17.0-54.0	30.3
Acid Soluble	12	6-21	15.3	12	19-24	21.7	12	5-70	35	12	17.0-48.0	31.3
Dissolved	12	6-13	9.1	12	10-19	13.0	12	12-47	24	12	5.3-9.4	7.0
Iron (ug/l)												
Total	12	136-335	248	12	148-165	155	12	274-721	487	12	195.0-763.0	390.0
Acid Soluble	12	97-260	193	12	124-158	141	12	197-471	369	12	193.0-652.0	402.3
Dissolved	12	21-21	21	12	15-15	15	12	27-492	170	11	10.0-17.0	13.5
Lead (ug/l)												
Total	12	1.0-6.5	1.5	12	1.0-4.8	2.7	12	1.0-5.0	2.2	12	1.0-5.7	1.5
Acid Soluble	12	1.0-1.7	1.1	12	1.0-1.5	1.1	12	1.0-5.0	1.7	12	1.0-5.0	2.9
Dissolved	12	1.0-1.8	1.1	12	1.0-1.0	1.0	12	1.0-2.0	1.1	12	1.0-2.6	1.1
Manganese (ug/l)												
Total	12	65-109	85	12	137-172	150	12	153-211	186	12	213-331	246
Acid Soluble	12	63-93	80	12	147-169	159	12	138-222	192	12	227-302	259
Dissolved	12	19-33	28	12	145-156	150	12	51-80	60	12	176-218	191
Zinc (ug/l)												
Total	12	56-103	77	12	155-193	173	12	74-151	113	12	57.0-224	115.6
Acid Soluble	12	60-124	81	12	147-210	176	12	58-155	112	12	71.0-284	151.7
Dissolved	12	13-144	36	12	130-149	138	11	14-122	33	11	9.0-25.0	15.8

Notes: (1) Statistics are computed with data for natural samples.
(2) For statistical purposes, values reported as below detection limits are treated as being at the reported detection limit.
(3) N/A--parameter not applicable.

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Table 2-9
(Continued)

SAMPLE SITE: SS-26; POND 2

Parameter	September 1987 n	Range	Average	January 1988 n	Range	Average	April 1988 n	Range	Average	July 1988 n	Range	Average
Potassium (ug/l)	12	4000-5400	4650	12	7250-8530	7790	12	3300-6540	4726	12	3400.0-4400.0	3742
Sodium (ug/l)	12	20800-24300	21775	12	26500-33100	29060	12	16200-22400	20100	12	18900-21900	20375
Sulfate (mg/l)	11	115-128	122	12	130-160	152	12	119-150	129	12	124-154	134
Chloride (mg/l)	12	10-11	10.8	12	13-16	14.5	12	11-12	11.0	12	9-10	9.5
Alkalinity (mg/l)	12	63-84	78	12	128-141	134	12	69-77	75.4	12	52-86	57.8
Chlorophyll "a" (mg/ml)	12	2-6	4.1	12	0.4-0.6	0.5	12	11.4-53.6	19.2	12	0.2-2.0	0.8
Phytoplankton (counts/ml)	12	1620-4010	2722	12	577-2300	1317	12	3380-7720	5433	8	35-1640	476
pH (S.U.)	12	7.7-9.0	8.3	11	7.0-7.7	7.4	12	7.9-9.1	8.8	12	9.7-10.4	10.1
DO (mg/l)	12	5.4-8.0	6.4	11	8.5-10.4	9.1	12	3.9-9.7	8.3	12	7.2-10.8	9.2
SC (umhos/cm)	12	397-450	427	11	574-634	601	12	427-494	452	12	361-396	384
Temperature (Co)	12	7-15	11.8	11	1.0-3.0	2.1	12	10-14	12.3	12	18-20	19.1
Flow (cfs)	N/A			N/A			N/A			N/A		
Hardness (mg/l)	12	164-197	174	12	267-324	294	12	151-220	187	12	135.4-153.9	144.6
Magnesium (ug/l)	12	13000-15300	13650	12	17500-21400	19250	12	10800-16500	13300	12	12700-14200	13458
Calcium (ug/l)	12	43600-53600	47358	12	77900-94600	85800	12	42700-60900	52875	12	32700-38200	35725
Aluminum (ug/l)												
Total	11	62-178	87	12	90-90	90	12	54-177	76.3	12	200-200	200
Acid Soluble	12	41-75	47	12	90-267	109	12	61-160	117.1	12	200-200	200
Dissolved	12	41-199	101	12	90-90	90	12	54-64	54.9	12	200-200	200
Arsenic (ug/l)												
Total	12	2.2-10.0	7.4	12	5.2-6.9	6.5	12	5.0-12.4	8.7	12	10.0-13.0	11.3
Acid Soluble	12	6.9-13.0	9.0	12	5.4-9.1	6.8	12	5.0-10.9	8.3	12	12.0-15.0	12.7
Dissolved	12	2.2-6.6	4.8	12	3.9-5.7	5.0	12	5.0-16.4	9.5	12	11.0-14.0	11.6
Cadmium (ug/l)												
Total	11	0.1-2.5	1.4	12	1.2-2.2	1.7	12	0.2-4.2	1.7	12	0.6-1.5	1.0
Acid Soluble	12	0.1-2.5	1.6	12	1.0-2.7	1.6	12	0.5-5.8	1.6	12	0.7-1.9	1.2
Dissolved	11	0.1-3.0	1.3	12	0.9-4.8	2.2	10	3.3-9.8	5.8	12	1.5-3.4	2.4
Copper (ug/l)												
Total	12	12.0-29.0	20.6	12	17-30	19.5	12	7.5-103	31.4	12	5.2-14.0	7.0
Acid Soluble	12	11.0-21.0	16.7	12	11-18	14.6	12	9.9-92	37.3	12	3.7-17.0	8.3
Dissolved	12	6.0-6.0	6.0	12	2.7-6.3	4.4	12	6.4-26	14.9	12	3.9-13.0	5.5
Iron (ug/l)												
Total	11	432-848	619	12	285-402	339	12	357-518	441	12	60.0-424.0	126.4
Acid Soluble	12	351-594	483	12	317-460	371	12	320-521	406	12	88.0-217.0	120.1
Dissolved	12	21-21	21	12	15-33	16.5	11	27-494	73	12	15.0-47.0	27.8
Lead (ug/l)												
Total	11	1.0-5.0	2.9	12	1.0-1.8	1.2	9	1.0-7.2	2.3	12	1.0-1.4	1.1
Acid Soluble	12	0.2-2.9	1.8	12	1.0-12.0	2.9	10	1.0-11.5	2.7	12	1.0-2.1	1.2
Dissolved	12	1.0-1.0	1.0	12	1.0-1.0	1.0	12	1.0-1.2	1.0	12	1.0-1.0	1.0
Manganese (ug/l)												
Total	12	81-243	131	12	329-580	446	12	352-1790	605	12	96.0-206.0	148.3
Acid Soluble	12	77-233	126	12	368-610	490	12	333-1650	575	12	100.0-220.0	155.3
Dissolved	12	8-200	85	12	278-568	474	12	210-1800	481	12	40.0-133.0	74.5
Zinc (ug/l)												
Total	11	48-124	74	12	126-191	148	12	41-536	102	11	8.0-39.0	21.0
Acid Soluble	12	56-74	64	11	146-335	194	11	63-514	138	12	27.0-161.0	73.9
Dissolved	11	7-50	17	12	52-76	65	12	11-386	47	12	5.0-12.0	6.8

Notes: (1) Statistics are computed with data for natural samples.
(2) For statistical purposes, values reported as below detection limits are treated as being at the reported detection limit.
(3) N/A--parameter not applicable.

CVR108/043-5

Table 2-9
(Continued)

SAMPLE SITE: PS-11B; WILDLIFE PONDS (IN-POND)

Parameter	September 1987 n	Range	Average	January 1988 n	Range	Average	April 1988 n	Range	Average	July 1988 n	Range	Average
Potassium (ug/l)	12	3100-6100	4575	13	7600-8170	7935	12	2350-4730	3528		3200-4800	3860
Sodium (ug/l)	12	19000-20700	20140	13	25400-27200	26446	12	16700-20100	18500		16500-21100	19092
Sulfate (mg/l)	12	111-175	120	12	110-210	125	12	104-124	116	12	115-120	118
Chloride (mg/l)	12	10-11	10.8	13	13-14	13.5	12	10.1-10.9	10.6	12	8.3-10.0	9.7
Alkalinity (mg/l)	12	61-73	67	13	117-120	119.8	12	67-73	69	12	50-63	58
Chlorophyll "a" (mg/ml)	12	2-9	5.0	13	0.4-2.2	0.9	12	31-54	40	12	0.7-1.7	1.2
Phytoplankton (counts/ml)	12	1690-4030	2978	13	549-2810	1492	12	9710-14800	11940	12	56-421	154
pH (S.U.)	10	6.9-9.1	8.3	13	7.7-8.0	7.9	12	8.6-9.4	9.1	12	8.9-9.3	9.1
DO (mg/l)	11	7.9-9.0	8.4	13	10.2-12.2	11.5	12	8.5-11.0	9.6	12	5.8-8.2	6.9
SC (umhos/cm)	12	5.8-9.0	12.7	13	475-512	491	12	394-427	411	12	364-383	375
Temperature (Co)	12	357-399	384	13	1-1	1.0	12	12-15	13.5	12	19-20	19.5
Flow (cfs)	N/A			N/A			N/A			N/A		
Hardness (mg/l)	12	135-154	143	13	226-243	235	12	143-185	161	12	138-155	145.8
Magnesium (ug/l)	12	10800-12200	11560	13	14500-16200	15370	12	9960-12400	11197	12	12400-13400	12908
Calcium (ug/l)	12	36300-42400		13	66400-70700	68907	12	40900-53400	45917	12	35000-39800	37100
Aluminum (ug/l)												
Total	11	41-116	54	13	90-90	90	12	54-111	72	12	96-200	165
Acid Soluble	12	41-45	42	13	90-1210	176	12	54-537	98	12	93-219	186
Dissolved	12	41-245	60	13	90-90	90	12	54-122	73	12	73-200	166
Arsenic (ug/l)												
Total	8	2.3-11.0	8.2	13	7.3-8.3	7.8	12	7.2-18.7	12.4	12	10-10	10.0
Acid Soluble	11	6.5-13.0	8.0	13	6.3-8.4	7.3	12	10.1-27.7	14.4	12	10-10	10.0
Dissolved	12	2.2-10.0	6.7	13	7.5-9.8	8.3	12	6.9-12.1	9.6	12	10-10	10.0
Cadmium (ug/l)												
Total	12	0.1-3.8	1.7	13	1-13	4.1	9	0.1-1.5	0.7	12	0.7-4.6	1.9
Acid Soluble	12	1.4-12.0	5.8	13	1.1-8.1	3.3	12	0.7-15.4	4.2	12	0.5-4.4	1.8
Dissolved	11	0.8-5.5	2.4	13	2-9.1	5.0	12	1.4-8.6	3.9	12	0.5-7.6	3.6
Copper (ug/l)												
Total	12	7.0-43.0	15.1	13	18-26	21.7	12	5-23	12.0	12	5.9-8.7	6.8
Acid Soluble	12	6.0-33.0	11.1	13	15-25	18.3	12	10-24	16.2	12	7.3-9.8	8.4
Dissolved	12	6.0-9.0	6.8	13	7.1-11	8.9	12	12-84	32.7	12	4.9-8.0	6.4
Iron (ug/l)												
Total	11	45-183	82	13	125-155	141	11	127-255	167	12	63-128	81.8
Acid Soluble	10	21-135	56	10	109-145	123	11	114-268	152	12	64-185	90.1
Dissolved	11	21-71	27	13	15-15	15	11	27-185	45	12	10-26	15.9
Lead (ug/l)												
Total	11	1.0-5.0	1.3	13	1.3-4.2	2.6	12	1.0-5.1	1.7	12	1.0-1.0	1.0
Acid Soluble	12	1.0-5.0	1.5	13	1-74	7.2	11	1.0-5.0	2.2	12	1.0-5.0	3.7
Dissolved	11	1.0-8.8	1.7	13	1-1	1.0	12	1.0-1.1	1.0	12	1.0-1.0	1.0
Manganese (ug/l)												
Total	11	40-77	48.3	13	51-68	57.7	12	167-188	177	12	35-83	44.8
Acid Soluble	11	34-51	37.8	13	52-87	61.7	11	160-200	182	12	36-83	48.0
Dissolved	12	4.0-28	16.3	13	50-58	53.8	12	32-53	39	12	21-64	31.0
Zinc (ug/l)												
Total	11	22-105	46.1	13	92-132	111	12	25-148	46	12	11-28	17.2
Acid Soluble	11	19-137	36.5	13	89-32700	2611	11	31-68	45	12	17-95	45.1
Dissolved	9	7-74	26.3	13	75-87	81	12	12-198	47	12	5.0-13.0	7.2

Notes: (1) Statistics are computed with data for natural samples.
(2) For statistical purposes, values reported as below detection limits are treated as being at the reported detection limit.
(3) N/A--parameter not applicable.

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Table 2-9
(Continued)

SAMPLE SITE: PS-11C; INFLOW TO WILDLIFE PONDS

Parameter	September 1987			January 1988			April 1988			July 1988		
	n	Range	Average	n	Range	Average	n	Range	Average	n	Range	Average
Potassium (ug/l)	12	3200-5900	4525	13	6600-7300	6830	12	2000-3440	2898	12	3880-4820	4198
Sodium (ug/l)	12	17400-21100	20283	13	23500-26600	25050	11	10900-20000	18400	12	19800-23700	20642
Sulfate (mg/l)	12	54-117	107	12	100-130	116	12	105-118	112	12	98-118	111
Chloride (mg/l)	12	11-11	11	13	13-20	14.2	12	9.9-11.0	10.4	12	8.5-10.0	9.4
Alkalinity (mg/l)	12	71-73	72.7	13	118-124	121	12	65-73	70	12	78-86	91
Chlorophyll "a" (mg/ml)	12	3-13	10.6	13	0.3-0.7	0.5	12	36-50	44	12	1.5-4.1	2.4
Phytoplankton (counts/ml)	12	800-8640	6504	13	344-1990	1105	12	6540-9510	7991	12	150-318	216
pH (S.U.)	11	7.4-9.6	8.3	13	7.9-8.2	8.0	12	9.2-9.3	9.3	12	8.1-8.4	8.3
DO (mg/l)	12	7.3-8.5	8.1	13	9.0-15.2	14.1	12	10.2-11.4	10.7	12	6.2-8.0	6.9
SC (umhos/cm)	12	376-408	397	13	476-502	493	12	366-393	381	12	390-431	414
Temperature (Co)	12	11-13	11.7	13	2-5	3.2	12	12-15	13.3	12	18-22	19.6
Flow (cfs)	N/A			N/A			N/A			N/A		
Hardness (mg/l)	12	128-153	148	13	214-233	226	12	90-164	151	12	158-183	165.5
Magnesium (ug/l)	12	9900-12100	11483	13	14100-15700	14830	12	6420-11700	10735	12	12100-14500	12858
Calcium (ug/l)	12	34900-42000	40183	13	62400-67300	65660	12	25500-46400	42800	12	43400-49300	45083
Aluminum (ug/l)												
Total	12	41-82	52.8	13	90-441	117	12	112-146	129	12	73-213	126.2
Acid Soluble	12	41-63	44.9	13	90-106	91	12	75-158	116	12	73-333	164.6
Dissolved	10	41-48	41.9	13	90-90	90	12	54-54	54	12	73-124	87.2
Arsenic (ug/l)												
Total	9	4.4-9.3	7.5	13	7.9-9.2	8.5	12	5.8-24.7	11.9	12	10.0-12.0	10.8
Acid Soluble	12	2.2-9.4	7.5	13	5.0-8.4	6.8	10	6.9-12.9	11.0	12	9.0-11.0	9.6
Dissolved	12	2.2-7.6	6.6	13	5.8-8.3	7.3	12	6.7-12.9	8.7	12	10.0-10.0	10.0
Cadmium (ug/l)												
Total	12	0.1-2.5	1.6	13	1.3-3.3	1.9	12	0.2-3.5	1.4	12	0.8-2.7	1.4
Acid Soluble	11	0.2-11.0	4.1	13	1.1-2.7	1.5	12	0.9-3.1	1.7	12	1.0-2.7	1.6
Dissolved	12	0.1-4.6	2.3	13	0.5-4.1	2.5	12	1.1-6.8	3.4	12	1.0-5.9	3.2
Copper (ug/l)												
Total	12	11.0-35.0	23.2	13	17-29	21	12	14-28	22.6	12	23-41	29.0
Acid Soluble	12	10.0-21.0	16.0	13	13-22	20	12	10-40	29.2	12	22-36	26.9
Dissolved	12	6.0-13.0	7.9	13	9.6-17	12.6	11	5-28	11.7	12	4.1-6.5	5.5
Iron (ug/l)												
Total	12	64-329	185	13	142-203	156	12	373-1120	620	12	288-610	394.3
Acid Soluble	12	76-249	165	13	134-164	141	12	219-789	388	12	235-530	359.3
Dissolved	11	21-21	21	13	15-15	15	10	27-149	44	12	15.0-60.0	19.3
Lead (ug/l)												
Total	12	1.0-1.0	1.0	13	1.0-2.4	1.6	12	1.0-4.1	2.1	12	1.0-4.4	1.3
Acid Soluble	12	1.0-2.4	1.2	13	1.0-1.2	1.0	12	1.0-2.3	1.2	12	1.0-2.0	1.3
Dissolved	12	1.0-1.7	1.1	13	1.0-1.0	1.0	12	1.0-1.9	1.2	12	1.0-1.0	1.0
Manganese (ug/l)												
Total	12	48-85	64.9	13	84-115	88.4	12	153-192	174	12	233-291	256
Acid Soluble	12	43-76	57.4	13	88-103	96.1	12	160-182	173	12	230-299	260
Dissolved	12	8-19	12.4	13	75-88	80.2	12	32-75	50	12	165-227	199
Zinc (ug/l)												
Total	10	42-102	71.6	13	131-201	154	12	78-161	111	12	81-162	111
Acid Soluble	12	44-134	79.6	13	146-295	176	12	81-133	106	12	89-195	129
Dissolved	9	10-116	31.2	13	89-123	108	12	11-115	29	11	14-36	19

Notes: (1) Statistics are computed with data for natural samples.
(2) For statistical purposes, values reported as below detection limits are treated as being at the reported detection limit.
(3) N/A--parameter not applicable.

Table 2-9
(Continued)

SAMPLE SITE: PS-12; POND 2 DISCHARGE

Parameter	September 1987			January 1988			April 1988			July 1988		
	n	Range	Average	n	Range	Average	n	Range	Average	n	Range	Average
Potassium (ug/l)	11	5300-6500	5700	13	7260-8220	7740	12	3240-5390	4235	12	3100-3500	3283
Sodium (ug/l)	11	17900-21000	20291	13	25700-30900	28160	12	18100-22200	20183	12	17500-18500	17992
Sulfate (mg/l)	12	115-134	125	12	130-170	150	12	112-130	122	12	125-158	141
Chloride (mg/l)	12	11-11	11	13	14-15	14.5	12	10-11.2	10.7	12	9.4-11.0	10.1
Alkalinity (mg/l)	12	71-76	73.5	13	127-138	132	12	71-83	74	12	53-62	5.7
Chlorophyll "a" (mg/ml)	12	1-2	1.3	13	0.1-0.7	0.5	12	9.7-24.6	18.3	12	0.3-0.9	0.6
Phytoplankton (counts/ml)	12	20-2000	1300	13	526-2030	1217	12	6030-10950	1681	6	212-831	534
pH (S.U.)	12	8.8-9.1	9.0	13	7.2-7.9	7.6	12	8.2-8.8	8.5	12	9.6-9.8	9.7
DO (mg/l)	12	5.6-10.8	8.8	13	8.4-12.0	9.4	12	5.4-9.8	7.8	12	6.3-8.9	8.0
SC (umhos/cm)	12	417-459	434	13	565-650	600	12	417-464	435	12	363-419	394
Temperature (Co)	12	8.5-17	12.3	13	1.0-3.0	1.9	12	11-14	12.5	12	18-21	19.6
Flow (cfs)	2	42.1-43.5	42.8	3	23.0-24.8	24.0	2	102-108	105.0	2	19.5-20.2	19.9
Hardness (mg/l)	12	157-170	163	13	267-301	285	12	168-191	178	12	155-162	159
Magnesium (ug/l)	12	13000-13900	13375	13	17400-20200	18700	12	11900-13700	12617	12	13700-14100	13900
Calcium (ug/l)	12	41300-45300	43408	13	77900-87500	82800	12	47600-53800	50533	12	39500-41500	40592
Aluminum (ug/l)												
Total	12	41-125	63.1	13	90-90	90	12	54-98	66.4	12	200-200	200
Acid Soluble	12	41-105	51.4	13	90-384	139	12	54-133	90.2	12	200-259	205
Dissolved	12	41-173	62.6	13	90-90	90	12	54-73	55.7	12	200-200	200
Arsenic (ug/l)												
Total	11	2.2-17.0	8.3	13	5.4-7.7	6.9	11	6.6-12.1	9.1	12	11.0-12.0	11.4
Acid Soluble	12	2.2-9.8	6.6	13	6.3-7.4	6.9	12	5.4-10.1	7.7	12	12.0-14.0	12.9
Dissolved	12	6.6-7.4	6.9	13	5.1-6.9	6.0	11	6.3-15.6	9.8	12	11.0-13.0	11.9
Cadmium (ug/l)												
Total	12	0.1-1.9	1.0	13	1.0-3.3	1.6	11	0.6-2.1	1.1	12	0.6-1.9	1.0
Acid Soluble	12	0.1-6.0	1.8	13	1.0-2.7	1.7	12	0.8-4.1	1.7	12	0.7-1.6	1.2
Dissolved	12	0.1-2.9	1.5	13	0.8-3.4	2.1	9	1.2-10.9	5.3	12	1.2-5.9	2.4
Copper (ug/l)												
Total	12	6.0-15.0	6.9	13	15-25	18.5	12	5-19	11.5	12	5.6-7.7	6.5
Acid Soluble	12	6.0-16.0	7.7	13	11-21	15.5	11	5-19	11.3	12	5.7-11.0	7.8
Dissolved	12	6.0-16.0	9.1	13	3.3-6.7	5.4	10	5-24	9.7	12	4.6-5.8	5.0
Iron (ug/l)												
Total	12	20-155	52	13	205-249	223	12	253-396	326	12	67-104	81.3
Acid Soluble	12	33-93	66	13	197-6680	793	12	250-368	288	12	39-148	79.1
Dissolved	11	20-21	21	13	15-16	15.1	11	27-40	28	12	13-29	19.5
Lead (ug/l)												
Total	11	1.0-1.0	1.0	13	1.0-3.4	1.4	6	1.0-1.0	1.0	12	1.0-1.1	1.0
Acid Soluble	12	1.0-1.1	1.0	13	1.0-25	2.9	12	1.0-4.9	2.6	12	1.0-1.2	1.0
Dissolved	11	1.0-7.5	1.6	13	1.0-1.0	1.0	12	1.0-2.1	1.1	12	1.0-1.0	1.0
Manganese (ug/l)												
Total	12	65-102	85	13	238-263	247	12	395-499	442	12	156-192	174.5
Acid Soluble	12	66-89	77	13	250-286	271	12	335-507	425	12	145-212	174.8
Dissolved	12	39-113	53	13	255-282	269	12	170-305	255	12	59-89	72.6
Zinc (ug/l)												
Total	12	18-38	25	13	122-150	131	12	25-58	34	12	9.0-70.0	20.1
Acid Soluble	11	9-69	27	10	129-292	167	12	43-75	56	12	7.0-128	67.0
Dissolved	7	7-23	10	13	76-95	85	12	11-82	25	12	5.0-10	7.5

Notes: (1) Statistics are computed with data for natural samples.
(2) For statistical purposes, values reported as below detection limits are treated as being at the reported detection limit.
(3) N/A--parameter not applicable.

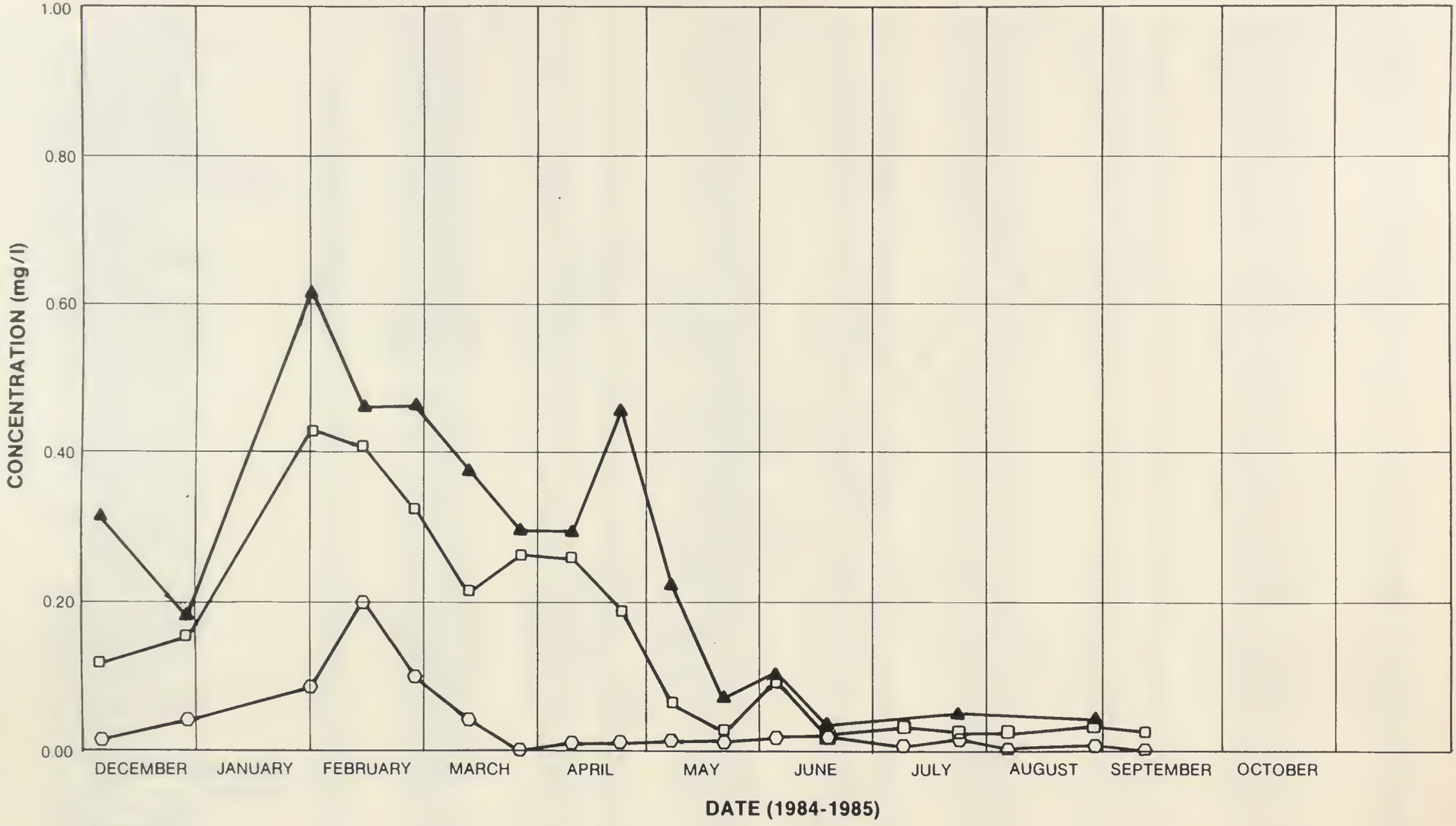

FIGURE 2-7

TOTAL ZINC CONCENTRATIONS AT POND 2

WARM SPRINGS PONDS
FEASIBILITY STUDY

B24856.E2

Although metals concentrations are reduced in the pond system, Montana's chronic freshwater aquatic standards for copper, lead, and zinc were exceeded throughout the pond system during the remedial investigation. Other metals frequently exceeded the standards. The numbers of exceedances at each of the sampling sites during the Phase I and Phase II remedial investigations are presented in Tables 2-10 and 2-11, respectively. Copper was the only metal that routinely exceeded the acute water quality standard for aquatic life.

Surface water quality data indicate Montana primary drinking water standards were not exceeded in the discharges (PS-12) from the Warm Springs Ponds system (Table 2-12). However, the primary drinking water standard for arsenic (0.05 mg/l) was exceeded in the Mill-Willow Bypass (Station SS-25, Figure 2-6) during the two highest measured flow events, and the arsenic standard was regularly exceeded in surface water pumped from below Pond 1 into Pond 1 (Station SS-27A, Figure 2-6) (Table 2-12).

The Mill-Willow Bypass exhibits increases in sulfate, hardness, and zinc concentrations between its head (SS-18) and its confluence with Pond 2 discharge (SS-25) (Figure 2-6). Synoptic flow measurements and a specific conductance survey completed during base flow conditions in the bypass confirmed that groundwater inflow along the Mill-Willow Bypass is responsible for the increases in concentrations of these parameters.

Four diurnal sampling episodes were completed at 8 to 10 sites within the Warm Springs Ponds system during the Phase II remedial investigation to gain a better understanding of changes in water quality over 24-hour periods and on

Table 2-10
WATER QUALITY STANDARD EXCEEDANCES FOR AQUATIC LIFE--
SAMPLING DURING
THE PHASE I REMEDIAL INVESTIGATION[a]

Sampling Station[a]	n[b]	Exceeding Chronic Standard[c]					Exceeding Acute Standard[c]				
		As	Cd	Cu	Pb	Zn	As	Cd	Cu	Pb	Zn
SS-19	10	0	3	10	8	10	0	0	10	0	10
SS-20	15	0	1	14	5	13	0	0	13	0	2
SS-21	18	0	2	17	5	18	0	0	17	0	2
SS-22	19	0	0	19	5	16	0	2	18	0	0
SS-26	15	0	4	14	6	11	0	0	14	0	4
PS-11A	18	0	0	9	1	3	0	0	8	0	0
PS-12	18	0	0	15	3	11	0	0	13	0	0
SS-18	14	0	0	10	1	2	0	0	8	0	0
SS-25	14	0	0	10	1	10	0	0	7	0	0

[a]Sampling station locations are shown on Figure 2-6.
SS-19: Silver Bow Creek above pond system
SS-20: Pond 3
SS-21: East decant discharge between Ponds 3 and 2
SS-22: West decant discharge between Ponds 3 and 2
SS-26: Pond 2
PS-11A: Wildlife Ponds discharge to Mill-Willow Bypass
PS-12: Pond 2 discharge to Mill-Willow Bypass
SS-18: Head of Mill-Willow Bypass
SS-25: Mill-Willow Bypass above Pond 2 discharge

[b]n = number of samples

[c]USEPA, 1986, 1985(a-d). Quality Criteria for Water. U.S. Superintendant of Documents, Washington, DC. Metals measured as total because total recoverable data are not available.

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Table 2-11

SUMMARY OF WATER QUALITY EXCEEDANCES
FOR THE PROTECTION OF AQUATIC LIFE--
DIURNAL SAMPLING COMPLETED DURING THE PHASE II RI
WARM SPRINGS PONDS AREA

Sample Station[a]	Sept. 1987		Jan. 1988		Apr. 1988		July 1988	
	n[b]	No. of Exceed[c]	n[b]	No. of Exceed[c]	n[b]	No. of Exceed[c]	n[b]	No. of Exceed[c]
SS-19								
Cadmium								
Chronic	12	9	12	12	12	11	12	9
Acute	12	6	12	0	12	1	12	0
Copper								
Chronic	12	12	12	12	12	12	12	12
Acute	12	12	12	12	12	12	12	12
Lead								
Chronic	12	9	12	2	12	11	12	4
Acute	12	0	12	0	12	0	12	0
Zinc								
Chronic	12	12	12	12	12	11	12	12
Acute	12	12	12	12	12	11	12	12
SS-20								
Cadmium								
Chronic	12	5	12	2	12	10	12	3
Acute	12	0	12	0	12	0	12	0
Copper								
Chronic	12	3	12	5	12	9	12	12
Acute	12	0	12	0	12	9	12	6
Lead								
Chronic	12	0	12	0	12	0	12	0
Acute	12	0	12	0	12	0	12	0
Zinc								
Chronic	12	0	12	2	12	1	12	1
Acute	12	0	12	2	12	1	12	0

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Table 2-11
(Continued)

Sample Station[a]	Sept. 1987		Jan. 1988		Apr. 1988		July 1988	
	n[b]	No. of Exceed[c]	n[b]	No. of Exceed[c]	n[b]	No. of Exceed[c]	n[b]	No. of Exceed[c]
SS-26								
Cadmium								
Chronic	12	5	12	1	12	2	12	2
Acute	12	0	12	0	12	0	12	0
Copper								
Chronic	12	2	12	0	12	7	12	1
Acute	12	0	12	0	12	7	12	0
Lead								
Chronic	12	0	12	0	12	1	12	0
Acute	12	0	12	0	12	0	12	0
Zinc								
Chronic	12	0	12	2	12	2	12	1
Acute	12	0	12	2	12	2	12	0
PS-11A								
Cadmium								
Chronic	12	4	12	0	12	0	12	0
Acute	12	0	12	0	12	0	12	0
Copper								
Chronic	12	0	12	0	12	0	12	0
Acute	12	0	12	0	12	0	12	0
Lead								
Chronic	12	0	12	0	12	1	12	0
Acute	12	0	12	0	12	0	12	0
Zinc								
Chronic	12	0	12	0	12	0	12	1
Acute	12	0	12	0	12	0	12	0

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Table 2-11
(Continued)

Sample Station[a]	Sept. 1987		Jan. 1988		Apr. 1988		July 1988	
	n[b]	No. of Exceed[c]	n[b]	No. of Exceed[c]	n[b]	No. of Exceed[c]	n[b]	No. of Exceed[c]
PS-12								
Cadmium								
Chronic	12	4	12	1	12	4	12	0
Acute	12	0	12	0	12	0	12	0
Copper								
Chronic	12	0	12	0	12	1	12	0
Acute	12	0	12	0	12	0	12	0
Lead								
Chronic	12	0	12	0	12	0	12	0
Acute	12	0	12	0	12	0	12	0
Zinc								
Chronic	12	0	12	1	12	0	12	0
Acute	12	0	12	1	12	0	12	0

[a]Sampling station locations shown on Figure 2-6.
[b]Number of natural samples collected.
[c]Number of samples exceeding USEPA standards (1976, 1986) (hardness dependent).

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Table 2-12
PRIMARY DRINKING WATER STANDARDS EXCEEDANCES
IN THE WARM SPRINGS PONDS SURFACE WATER

Date	Parameter	Silver Bow Creek Above Ponds SS-19	Mill-Willow Bypass SS-18	Mill-Willow Bypass SS-25	Opportunity Ponds Discharges SS-23	Opportunity Ponds Discharges SS-24	Pond 2 SS-26	Pond 1 Pump-back SS-27A	Standard[a]
12/05/84	Pb				0.129	0.192			0.05
01/30/85	Cd						0.012		0.01
02/27/85	As							0.097	0.05
03/27/85	As							0.091	0.05
04/10/85	As							0.128	0.05
04/23/85	As							0.108	0.05
06/05/85	As		0.105	0.120					0.05
05/31/86	As			0.052					0.05
06/05/86	As	0.073	0.105						0.05

[a]USEPA, 1985a,b,d. Quality Criteria for Water. U.S. Superintendent of Documents, Washington, DC.
Note: Concentrations in mg/l.

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a seasonal basis. Diurnal sampling events were completed in September 1987 and in January, April, and July 1988.

Table 2-9 summarizes field and laboratory data for the diurnal sampling events. These data indicate the following:

- pH varied measurably at all stations sampled. The magnitude of variation over a 24-hour period was more pronounced (up to 2.2 pH units) during the September and July sampling events, than during the January event (up to 0.7 pH units). The greatest variability in pH was measured at the inflow to the pond system (SS-19) (Figure 2-8). The measured variability at the station is likely reflective of the variability of upstream inputs, particularly the Butte Sewage Treatment Plant discharge.

- The greatest variability of potassium, sodium, sulfate, and chloride concentrations occurred at the inflow to the pond system (SS-19). This phenomenon also may be related to the variability of upstream inputs (particularly the Butte sewage treatment plant) and to runoff conditions which were evident during the April sampling episode.

- Alkalinity concentrations decreased from inflow to the outflow during the September, April, and July sampling episodes, but increased during the January sampling episode. This is probably caused by the consumption of carbon dioxide when photosynthesis occurs at rates greater than respiration, and the production of carbon dioxide when the respiration rate is greater than that of photosynthesis.

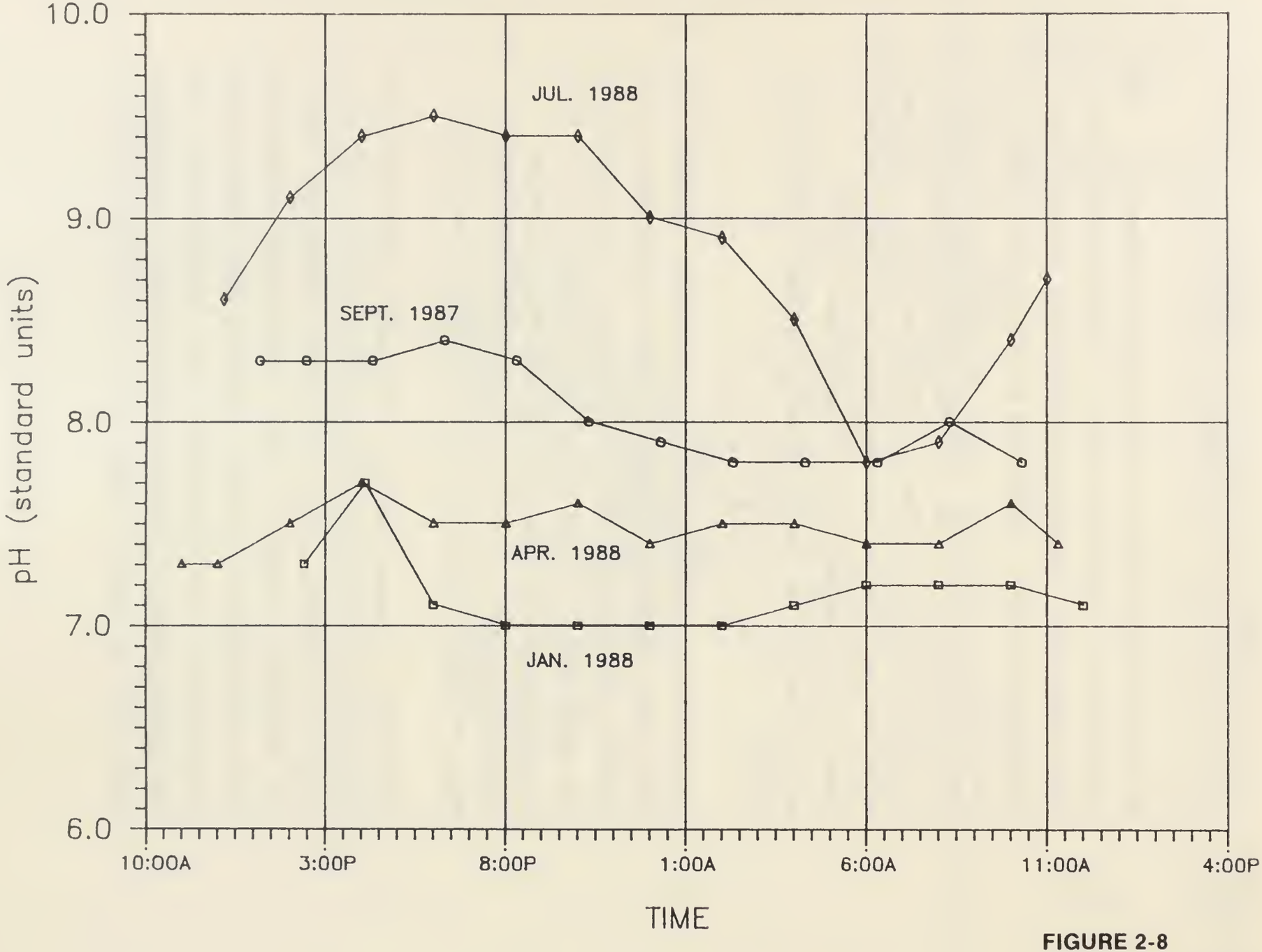

FIGURE 2-8

pH VALUES AT SS-19
SILVER BOW CREEK CERCLA
WARM SPRINGS PONDS
FEASIBILITY STUDY

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- The greatest magnitude in chlorophyll-a concentrations and in phytoplankton counts occurred at the inflow to the pond system from Silver Bow Creek (SS-19). Phytoplankton counts consistently decreased through the pond system. Silver Bow Creek has a large nutrient supply because of discharges from the sewage treatment plant in Butte. As the water moves through the ponds, most of the nutrients are consumed, resulting in less algae.

Metals data obtained during the diurnal sampling events suggest the following:

- Metals concentrations decreased 50 to 90 percent between pond system inflow and outflows.

- Diurnal variations were evident in dissolved zinc concentrations at the inflow to the pond system (SS-19). An example of this phenomenon for the September sampling event is shown on Figure 2-9. These variations seem to be related to variations in pH.

- Dissolved metals concentrations were higher in the winter at all sampling stations in the pond system. Higher dissolved metals concentrations in the winter correlate directly with lower pH values measured during winter sampling events.

Based upon the foregoing analyses, it appears the Warm Spring Ponds exhibit diurnal and seasonal water quality variability. This is especially pronounced at the inflow to the system. Within the pond system, temperature, pH, dissolved oxygen, specific electrical conductivity, and chlorophyll-a varied diurnally at several locations.

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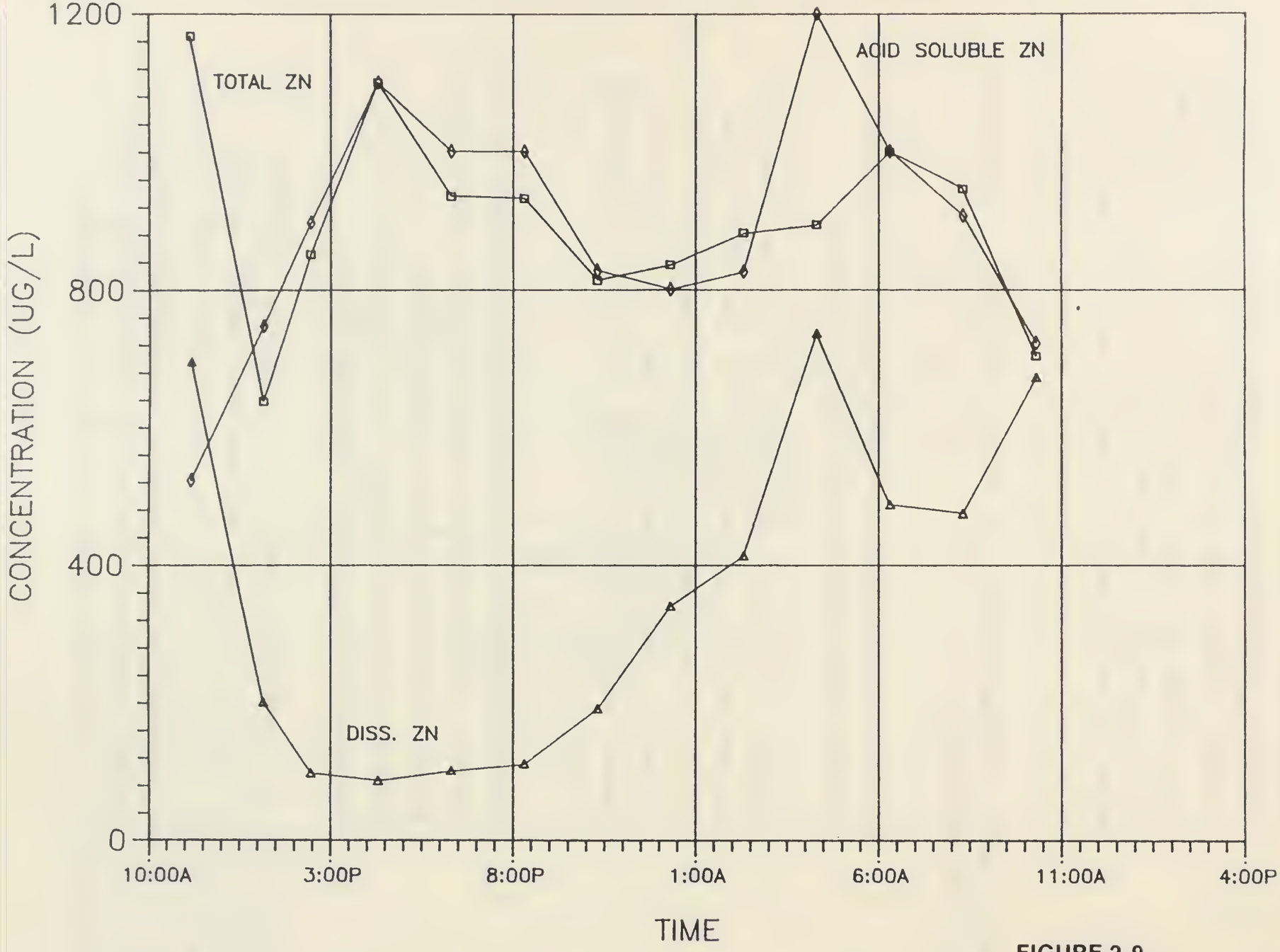

FIGURE 2-9

ZINC CONCENTRATIONS AT SS-19
SEPTEMBER 1987
WARM SPRINGS PONDS
FEASIBILITY STUDY

However, the pond system was effective in reducing metals concentrations to near both chronic and acute aquatic standards at the outflows from the system during the four diurnal sampling events (Table 2-11). Figure ES-5 shows an example of the metals reduction through the pond system.

The wide variability of measured parameters at the inflow to the pond system (SS-19) is probably indicative of varying inputs to Silver Bow Creek upstream of the pond system and the diurnal effects of photosynthesis and respiration in the creek.

Removal of metals in the ponds is probably accomplished by physical, chemical, and biologically mediated processes. In the latter, increases in pH as a result of photosynthesis can precipitate metals as a result of changing metals solubilities. Another important biologically mediated mechanism may be precipitation of calcite and coprecipitation of metals and phosphorus; which can result from photosynthetic removal of carbon dioxide and compensating shifts in the bicarbonate buffering system.[23] Direct uptake or absorption of metals by algae and aquatic macrophytes is also probable. Both passive and active uptake of metals and protons by algae have been demonstrated.[24]

The diurnal variation in pH and dissolved oxygen at pond locations (PS-20, PS-11B, and SS-27) and the pond outlets (PS-11A, SS-22, and PS-12) (see Figure 2-6) suggests a fairly strong pattern of daily photosynthesis and respiration. However, the concentrations of chlorophyll-a that were measured

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[23] Wetzel, R.G., 1975. Limnology. Philadelphia: W.B. Saunders Company.

[24] Crist, R.H., K. Oberholser, D. Schwartz, J. Marzoff, D. Ryder, and D.R. Crist., 1988. Interactions of Metals and Protons with Algae. Environmental Sciences and Technology. 22:755-760.

do not indicate the density of planktonic algae at the pond stations that would typically cause large variations in pH and photosynthetic precipitation of calcite.[25] For example, Murphy et al. observed calcite precipitation in a naturally entrophic lake with chlorophyll-a concentrations of up to 1 mg/m^3 at the lake surface; they demonstrated calcite and phosphorus precipitation in that lake during periods of intense photosynthesis.[26]

High phytoplankton concentrations are not necessary for photosynthetic precipitation of calcite and phosphorus and, by inference, coprecipitation of metals.[27,28] Photosynthetic precipitation of calcite and silicate can even occur under circumstances of relatively low hardness and nutrient concentrations. This phenomenon has been observed on the delta of the Flathead River at Flathead Lake, Montana.[29]

It is likely that planktonic algae, algal mats, and macrophytes all contribute to reduction in concentrations of metals in flows through the Warm Springs Ponds. This condition was evident in the reduced metals removal efficiencies measured during the winter months.

Few high-flow data are available to characterize the Warm Springs Ponds surface water quality under runoff conditions

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25 Wetzel, 1975.

26 Murphy, T.,P., K.J. Hall, and I. Yesaki, 1983. Coprecipitation of Phosphate With Calcite in a Naturally Entropic Lake. Limnology and Oceanography, Vol. 28. No. 1.

27 Goulder, R., 1969. Interactions Between Rates of Production of a Freshwater Macrophyte and Photoplankton in a Pond. Oikos. 20:300-309.

28 Wetzel, 1975.

29 Moore, J.N., 1983. The Origin of Calcium Carbonate Nodules Forming on Flathead Lake Delta, Northwestern Montana. Limnology and Oceanography. 28:646-654.

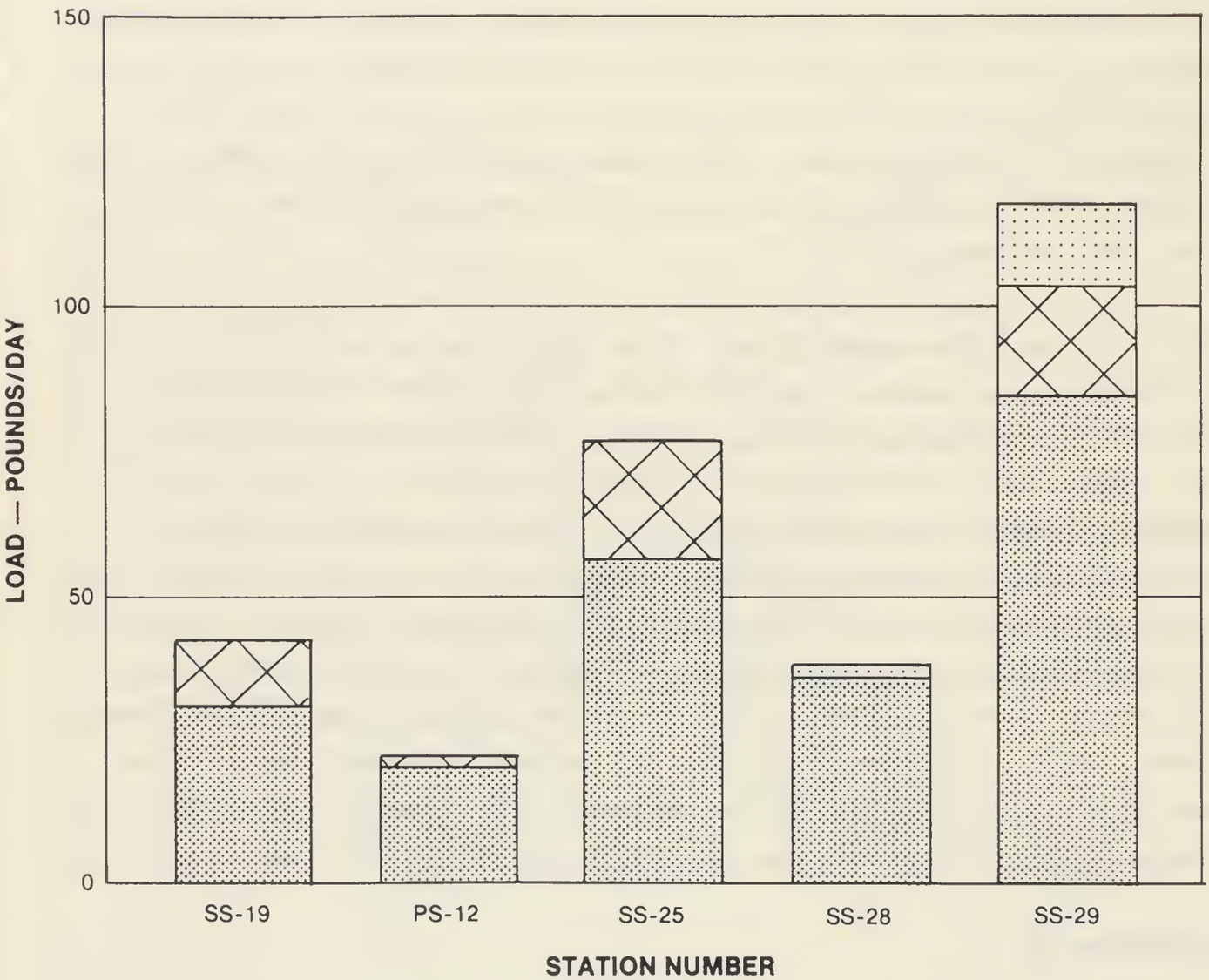
because of drier-than-normal conditions the area experienced during the remedial investigation. Samples collected during a relatively high flow event (about 200 cfs) on Silver Bow Creek during May 1986 did not contain high metals concentrations because the majority of the runoff originated in the relatively uncontaminated German Gulch drainage, a tributary to Silver Bow Creek. The largest metals loads (arsenic and copper) to the Clark Fork River during this event were derived from the Mill-Willow Bypass and Warm Springs Creek (Figures 2-10 and 2-11). Data have not been collected during runoff events that cause flows to be diverted around the pond system.

Fishkills on the upper Clark Fork River have occurred during thunderstorm events. Analysis of fish tissue by Montana Department of Fish, Wildlife, and Parks from one event in the summer of 1986 revealed copper poisoning as the cause of the fish mortality (MDFWP files). Although MDFWP did not determine the source of metals responsible for the kills, that source most likely consists of tailings material along the Mill-Willow Bypass. At the time of the 1986 fishkill, the ponds provided protection from metal loads in Silver Bow Creek, and no direct diversion of water occurred from Silver Bow Creek to the Mill-Willow Bypass. Chapter 4 discusses the probable cause of the fishkills in more detail.

GROUNDWATER

Physical Characterization

A shallow groundwater system is present throughout the year in much of the Warm Springs Ponds Operable Unit. The area is typified by bogs and swampy areas. Four major ponded surface water bodies (Ponds 1, 2, and 3, and the wildlife ponds) also influence local groundwater occurrence. Depth



LEGEND

- TOTAL
- ACID SOLUBLE
- DISSOLVED

SS-19 SILVER BOW CREEK ABOVE UPPER pH SHACK
PS-12 POND 2 DISCHARGE
SS-25 MILL-WILLOW BYPASS ABOVE POND 2 DISCHARGE
SS-28 WARM SPRINGS CREEK AT U.S.G.S. GAGING STATION
SS-29 CLARK FORK RIVER AT PERKINS LANE BRIDGE

FIGURE 2-10

ARSENIC LOADS
MAY 31, 1986
WARM SPRINGS PONDS
FEASIBILITY STUDY

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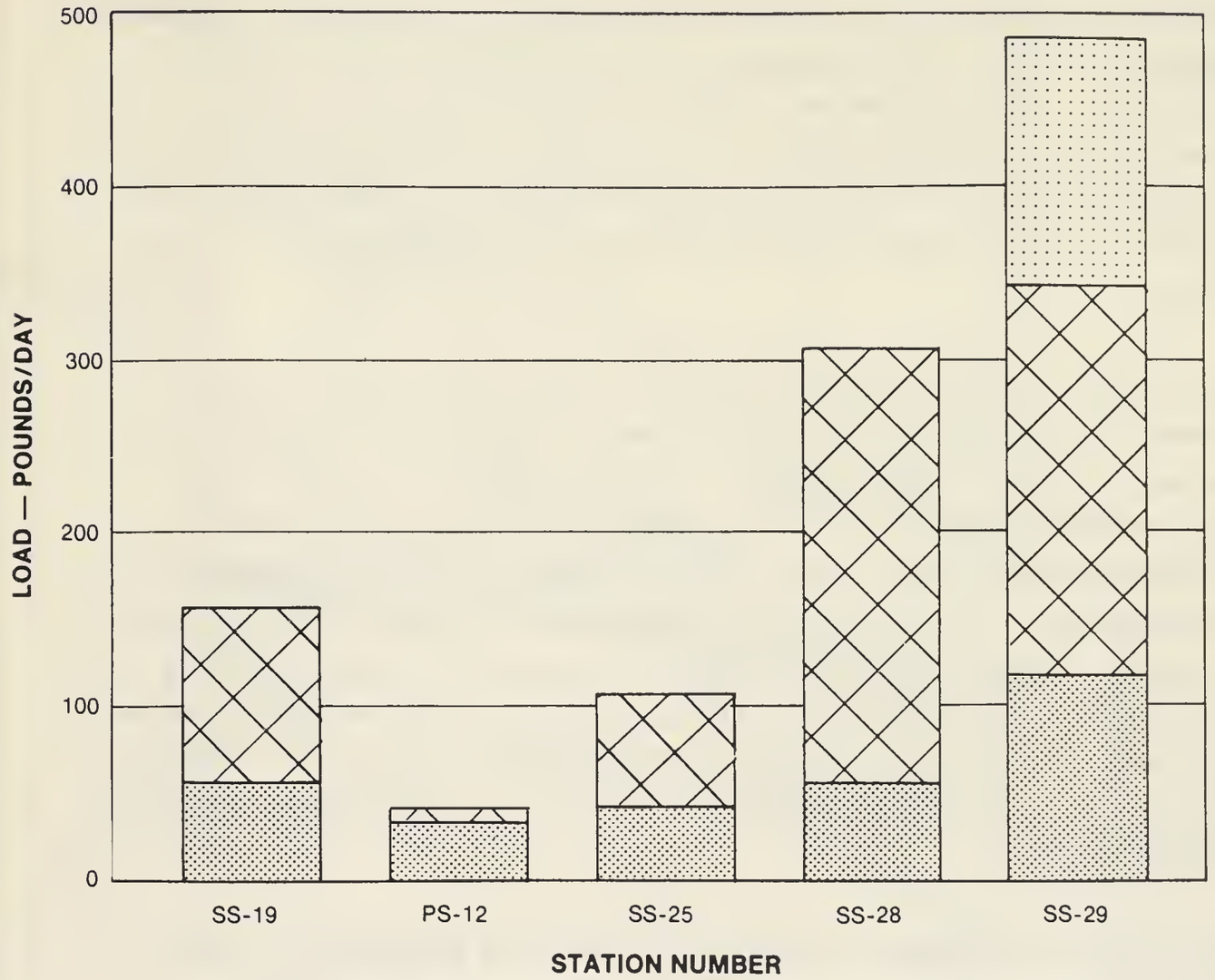

LEGEND

TOTAL
ACID SOLUBLE
DISSOLVED

SS-19: SILVER BOW CREEK ABOVE UPPER pH SHACK
PS-12: POND 2 DISCHARGE
SS-25: MILL-WILLOW BYPASS ABOVE POND 2 DISCHARGE
SS-28: WARM SPRINGS CREEK AT U.S.G.S. GAGING STATION
SS-29: CLARK FORK RIVER AT PERKINS LANE BRIDGE

FIGURE 2-11

COPPER LOADS
MAY 31, 1986
WARM SPRINGS PONDS
FEASIBILITY STUDY

B24856.E2

to groundwater below ground surface ranges from about 1 foot to 10 feet. Groundwater levels fluctuated approximately 2 feet during 1988; highest groundwater levels occurred during spring, and lowest groundwater levels generally occurred during fall-winter months.

Aquifers present at the site are generally in coarse-grained deposits within the Quaternary and Tertiary unconsolidated material. The uppermost aquifer at the site is a 10- to 15-foot-thick sand and gravel unit, which is typically present approximately 10 feet below ground surface. This sand and gravel aquifer appears to be present throughout most of the site.

The near-surface aquifer is typically underlain by relatively low permeability fine-grained units that locally act as aquitards. The thickness of the aquitard ranges from approximately 2 to 7 feet. The aquitard is not laterally continuous throughout the entire area. A fine- to medium-grained sand unit typically underlies the aquitard at depths ranging from 15 to 25 feet below ground surface. Beneath the sand unit are alternating sequences of fine- and coarse-grained units that are not laterally correlatable. Groundwater is generally encountered in many of the coarse-grained deeper units.

Groundwater movement through the site is generally south to north, although a significant component of groundwater enters from the Opportunity Ponds area to the southwest. Figure 2-12 is a potentiometric map showing groundwater movement in the area. Average groundwater gradients associated with Silver Bow Creek entering from the south are on the order of 0.3 percent; the groundwater component entering from the southwest exhibits a gradient of approximately 0.7 percent. A separate groundwater system enters the Warm

FIGURE 2-12

WATER TABLE MAP
WARM SPRINGS PONDS
FEASIBILITY STUDY

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Springs Ponds Operable Unit from the foothills east of the site. Available data indicate this groundwater system exhibits a subtle gradient to the west of a magnitude similar to that system entering the area from the south.

Vertical groundwater gradients also exist between the various aquifers present in the Warm Springs Ponds Operable Unit. Most data on this phenomenon are for the area north of Pond 1. The magnitude of the measured vertical gradients in the groundwater system north of Pond 1 ranges from approximately 4 percent upward to 0.4 percent downward. Metals contamination at the site is generally related to the three-dimensional mechanics of groundwater movement. Relatively higher concentrations of arsenic and cadmium are present in the area north of Pond 1, which exhibits an upward groundwater gradient.

Slug tests were completed at all monitoring wells in the Warm Springs Ponds Operable Unit. Slug tests involve inserting or extracting a cylindrical apparatus of a known dimension into the well and monitoring the reaction of water levels within the wells. These data indicate aquifers in the area exhibit permeabilities ranging from 40 to 400 gpd/ft^2. Pumping tests (constant drawdown tests) completed at wells constructed north of Pond 1 and adjacent to the Mill-Willow Bypass produced permeability values in the shallow sand and gravel on the order of 1,500 to 2,000 gpd/ft^2. The pumping test data are more characteristic of site hydrogeologic conditions than slug test data because of the length of pumping tests and the ability of the pumping tests to stress the aquifers.

Permeabilities are generally higher in the uppermost sand and gravel aquifer as compared to the subjacent sand aquifer. Based on pumping test data, the hydraulic connection is weak

between the shallow sand and gravel aquifer and the underlying sand aquifer. Total groundwater flux exiting the pond system north of Pond 1 through the shallow sand and gravel aquifer is approximately 1 cubic foot per second (cfs).[30]

The volume of groundwater currently entering the Mill-Willow Bypass from the Warm Springs Ponds is approximately 2.5 cfs. The majority of this inflow appears to enter the Bypass in the area adjacent to ponded water in Ponds 2 and 3 and the wildlife ponds because of the hydraulic head difference between the elevation of water in the ponds and the elevation of water in the bypass channel. Inflow of groundwater to the bypass is also derived from the Opportunity Ponds area, west of the bypass channel. Calculated inflow to the bypass channel from this source is approximately 0.7 cfs. Synoptic flow measurements in the bypass channel during a time period in which the surface water of Mill and Willow Creeks was being diverted into Pond 3 confirmed these groundwater inflow calculations.

Quality Characterization

Groundwater quality data were generated through sampling of 19 monitoring wells on two occasions (January and May, 1988). Fourteen of the 19 wells were constructed as well pairs to provide groundwater quality data from both the shallow sand and gravel aquifer and the underlying sand aquifer. Figure 2-13 shows the locations of the monitoring wells at the site. Table 2-13 summarizes groundwater quality data for these monitoring wells. Figures 2-14 through 2-18 depict spatial relationships in groundwater chemistry in both the shallow and deeper aquifers.

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30 CH2M HILL, 1989.

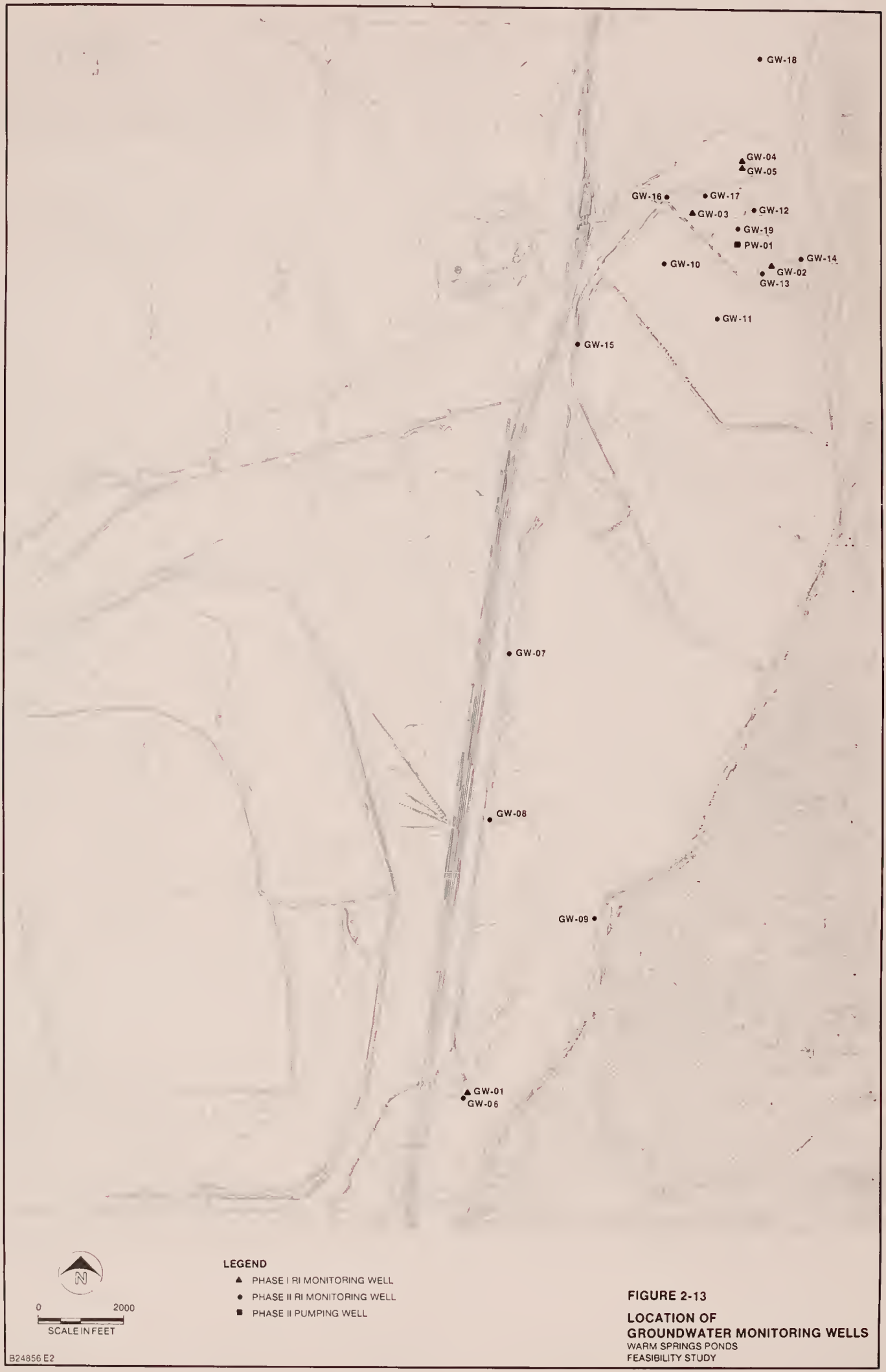

FIGURE 2-13

LOCATION OF GROUNDWATER MONITORING WELLS
WARM SPRINGS PONDS
FEASIBILITY STUDY

B24856.E2

Table 2-13
GROUNDWATER QUALITY DATA SUMMARY
WARM SPRINGS PONDS OPERABLE UNIT

Parameter	Maximum Concentration[a]	Minimum Concentration[a]	Average Concentration[a]	Number of Samples	Maximum Contaminant Level[a] (Montana Groundwater Regulations)
Upgradient Monitoring Wells					
Arsenic	6.8	2.6	4.3	8	50[b]
Cadmium	7.0	<5.0	3.4	8	10[b]
Copper	9.7	6.1	5.8	8	1,000[c]
Lead	1.2	<1.0	0.84	8	50[b]
Manganese	22.0	<3.0	7.3	8	50[c]
Zinc	21.2	4.7	10.3	7	5,000[c]
Iron	28.0	<15.0	19	8	300[c]
Sulfate (mg/l)	68.0	23	49	8	250[c]
Mill-Willow Bypass (Shallow Wells)					
Arsenic	41.0	<2.0	9.2	10	50[b]
Cadmium	11.7	<5.0	3.7	10	10[b]
Copper	15.0	<6.0	4.6	10	1,000[c]
Lead	18.0	<1.0	2.5	10	50[b]
Manganese	14,500	45	4,755	10	50[c]
Zinc	1,250	12.7	265	10	5,000[c]
Iron	4,000	25.0	805	10	300[c]
Sulfate (mg/l)	1,130	60.0	563	10	250[c]
Mill-Willow Bypass (Deep Wells)					
Arsenic	<2.0	<2.0	1.1	8	50[b]
Cadmium	5.2	<5.0	2.9	8	10[b]
Copper	7.1	<6.0	4.0	8	1,000[c]
Lead	2.0	<1.0	1.1	8	50[b]
Manganese	8,550	7.0	2,121	8	50[c]
Zinc	38.0	6.2	22.2	8	5,000[c]
Iron	70	<15	33	8	300[c]
Sulfate (mg/l)	1,060	92.0	494	8	250[c]
Downgradient of Pond 1 (Shallow Wells)					
Arsenic	197.0	<2.0	28.0	14	50[b]
Cadmium	12.7	<5.0	3.6	14	10[b]
Copper	15.9	<6.0	5.8	14	1,000[c]
Lead	<2.0	<1.0	2.0	14	50[b]
Manganese	31,600	309	10,297	14	50[c]
Zinc	253	16.3	89.0	14	5,000[c]
Iron	80,900	45	16,220	14	300[c]
Sulfate (mg/l)	1,620	250	950	14	250[c]
Downgradient of Pond 1 (Deep Wells)					
Arsenic	<3.0	<2.0	1.0	13	50[b]
Cadmium	8.4	<5.0	4.3	13	10[b]
Copper	<8.0	<6.0	3.5	13	1,000[c]
Lead	<2.0	<1.0	0.8	13	50[b]
Manganese	4,460	3.0	577	13	50[c]
Zinc	43	6.2	19.8	13	5,000[c]
Iron	409	<15	52	13	300[c]
Sulfate (mg/l)	1,150	55	531	13	250[c]

[a]
[b] All values in ug/l unless otherwise noted.
[c] Primary standard (based on health criteria).
Secondary standard (based on suitability criteria).

Notes:
1. Upgradient wells include WSP-GW-01, 06, and 09 (Figure 2-13).
2. Shallow wells are generally less than 15 feet deep; deep wells are generally 25 to 40 feet deep.
3. Mill-Willow shallow wells include WSP-GW-07S, 08S, 15S, 16S, and 17 (Figure 2-13).
4. Mill-Willow deep wells include WSP-GW-07D, 08D, 15D, and 16D (Figure 2-8).
5. Shallow wells downgradient of Pond 1 include WSP-GW-02S, 03S, 05, 12S, 13S, 14S, and 19S (Figure 2-13).
6. Deep wells downgradient of Pond 1 include WSP-GW-02D, 03D, 04, 12D, 13D, 14D, and 19D (Figure 2-13).
7. Average values calculated using one-half detection limit, when applicable. January and May 1988 data.

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Groundwater beneath Ponds 2 and 3 may be contaminated also. Wells were not installed to determine the quality of the groundwater beneath the two ponds. Given the hydrogeology of the site, contaminated groundwater under the ponds would flow north and be detected at the northern end of the pond system.

Several parameters measured in groundwater samples collected from monitoring wells indicate the groundwater system within the operable unit is degraded from the southern end of Pond 3 to north of the northern edge of the area. The best examples of parameters indicative of degraded groundwater in the operable unit are sulfate, iron, and manganese. The approximate extent of groundwater contamination based upon these parameters, pore water data from Ponds 2 and 3,[31] and results of an electromagnetic survey completed in the area is shown on Figure 2-19.

The electromagnetic survey was completed using an instrument capable of externally measuring the specific conductance of shallow groundwater in the area. This type of study provides a means of mapping the lateral extent of groundwater contamination based upon differing specific conductivity values.[32]

Groundwater quality data for monitoring wells located between the Warm Springs Ponds and the Mill-Willow Bypass indicate elevated metals concentrations compared to upgradient monitoring wells. Only one sample obtained from monitoring wells located adjacent to the bypass exceeded maximum

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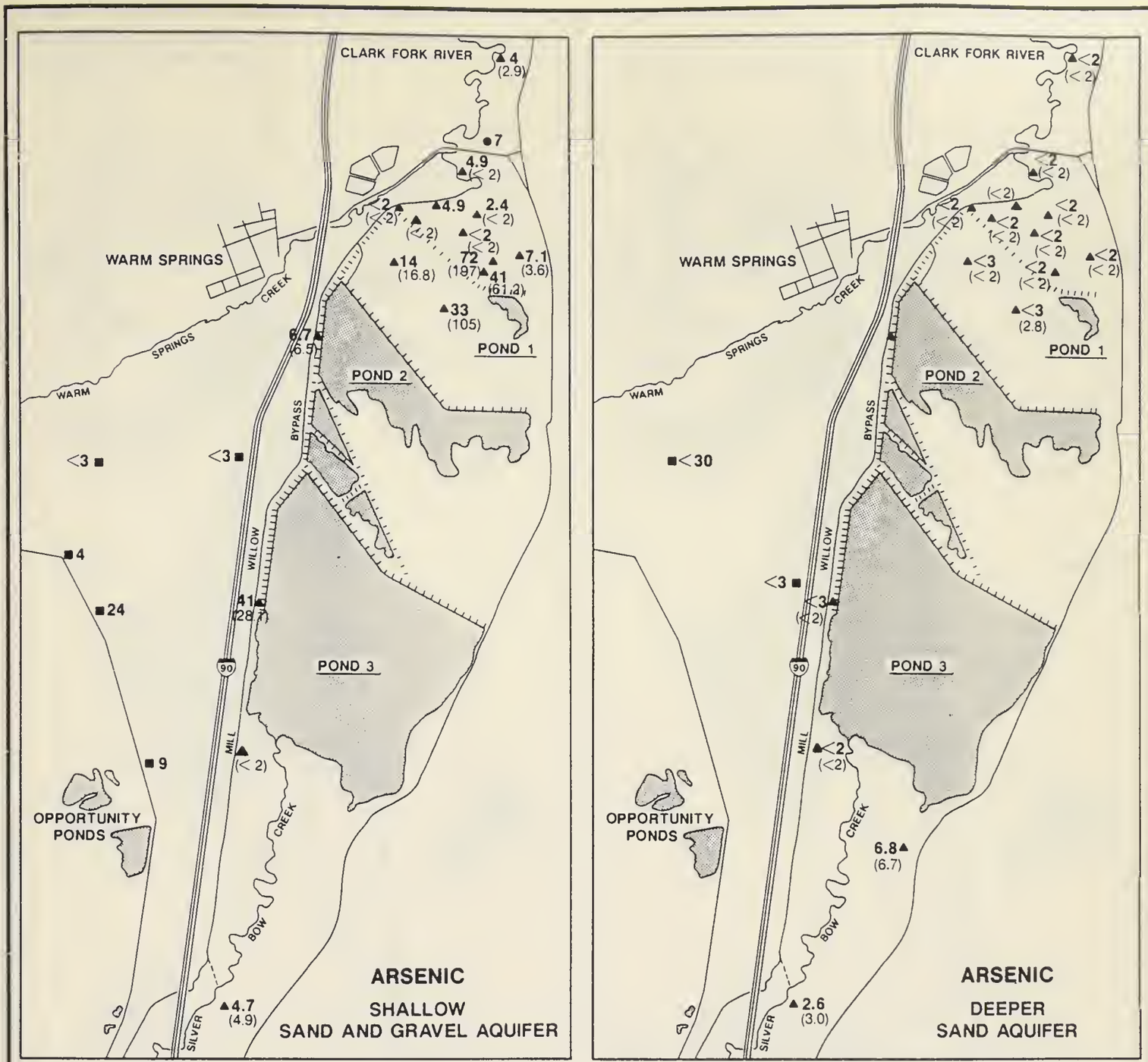
31 CH2M HILL, 1989.

32 For results of the electromagnetic survey, see CH2M HILL, 1989.



LEGEND

- ▲ Phase I and II RI Monitoring Wells
- 4.9 Sampled December 1987 and January 1988
- (3.0) Sampled May, 1988
- ● U.S.G.S. Monitoring Wells Sampled January 1987
- ■ Anaconda Smelter RI Monitoring Wells Sampled October 1985

N

NTS

FIGURE 2-14

CONCENTRATIONS OF DISSOLVED ARSENIC IN GROUNDWATER (μg/l)

WARM SPRINGS PONDS
FEASIBILITY STUDY

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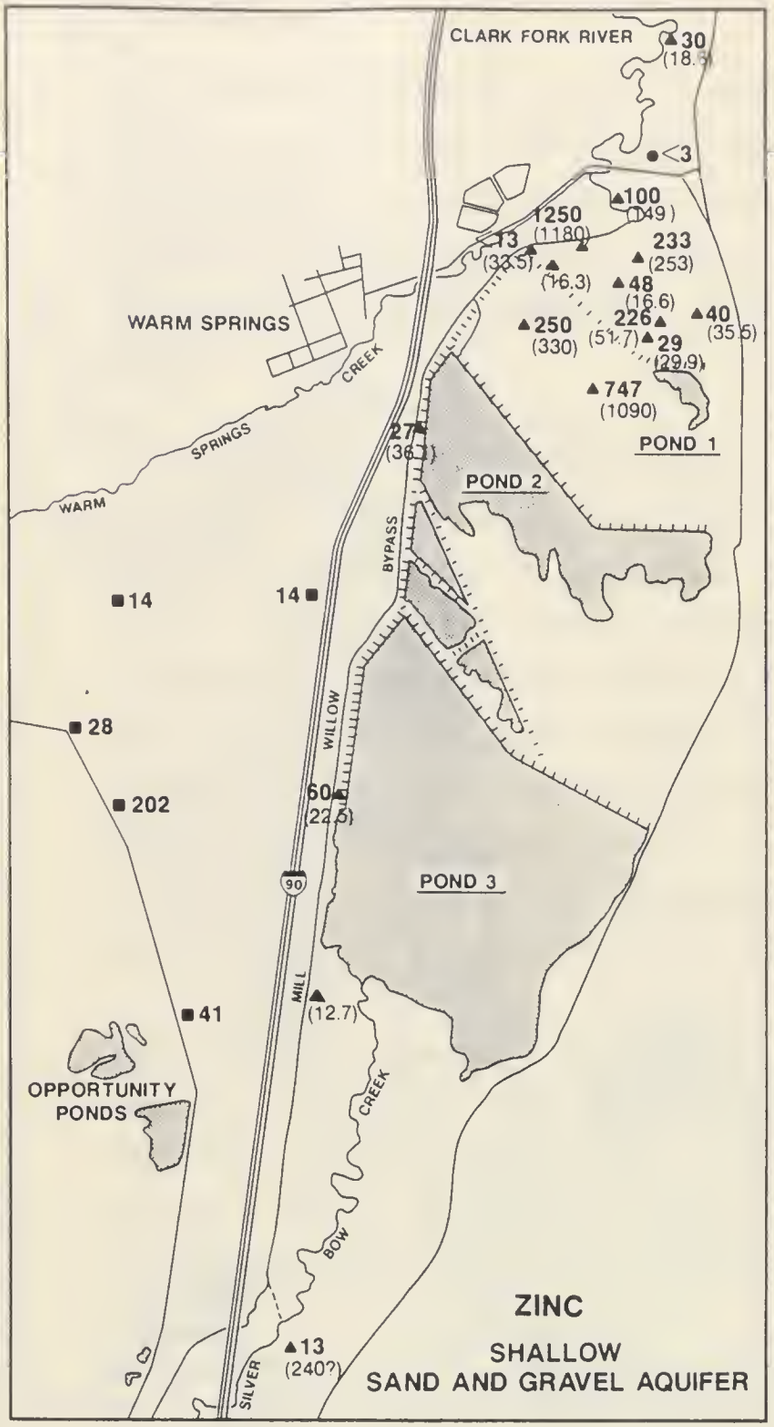

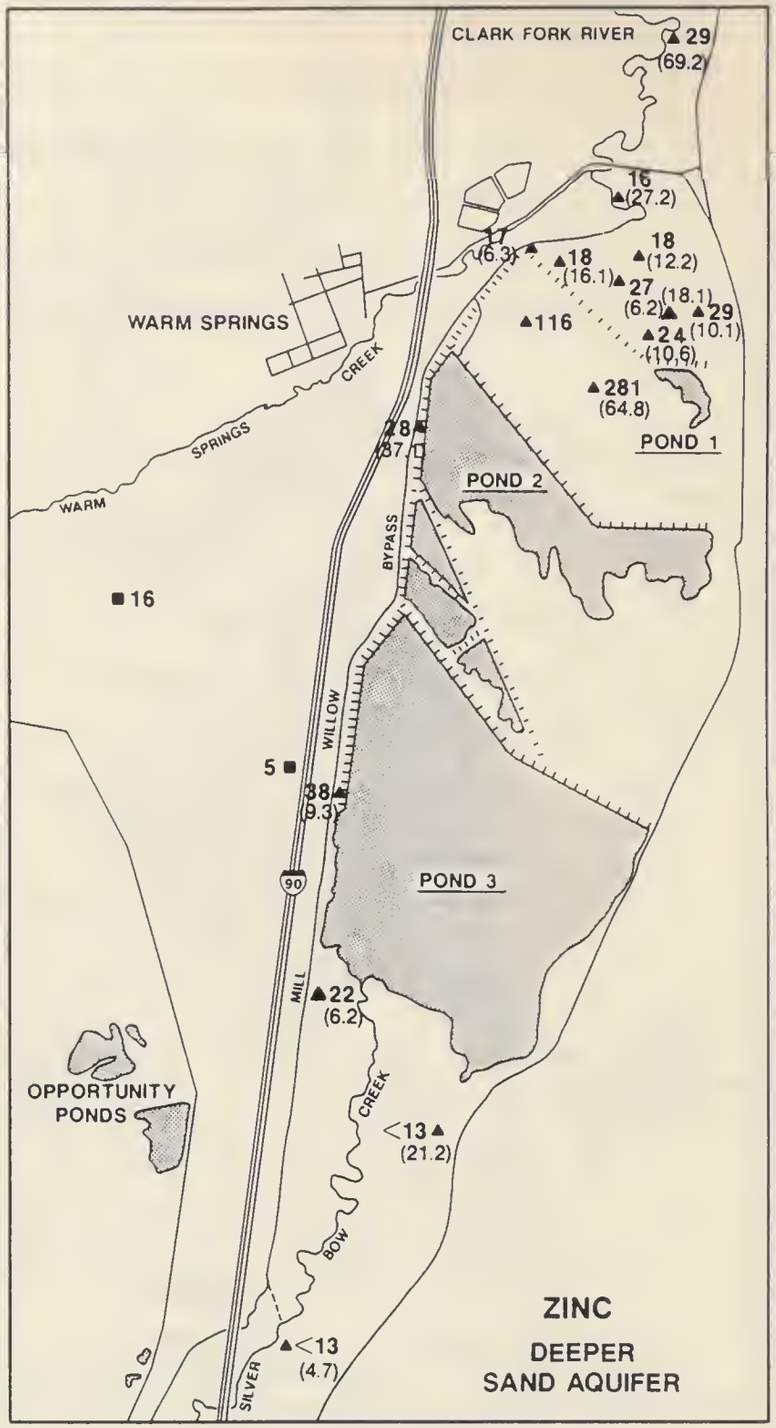

LEGEND

- ▲ Phase I and II RI Monitoring Wells
- 13 Sampled December 1987 and January 1988
- (12.7) Sampled May, 1988
- ● U.S.G.S. Monitoring Wells
  Sampled January 1987
- ■ Anaconda Smelter RI Monitoring Wells
  Sampled October 1985

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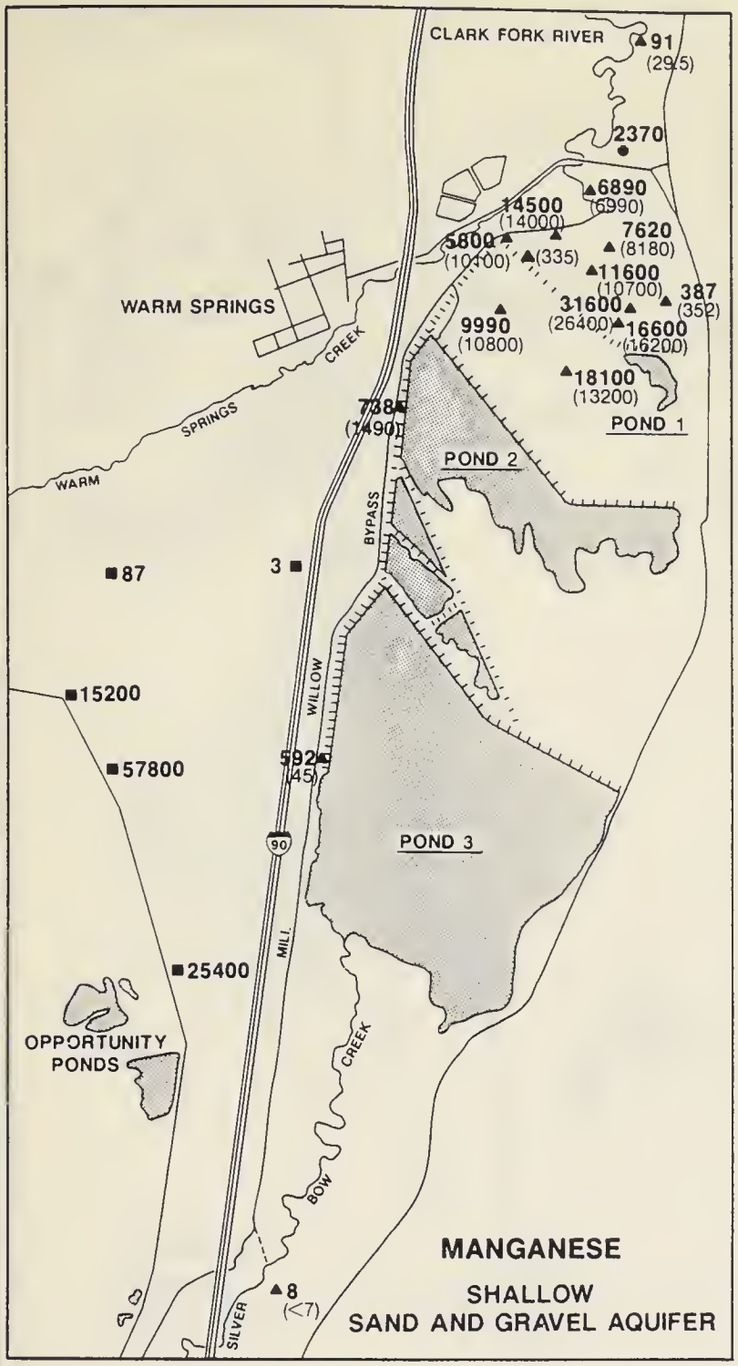
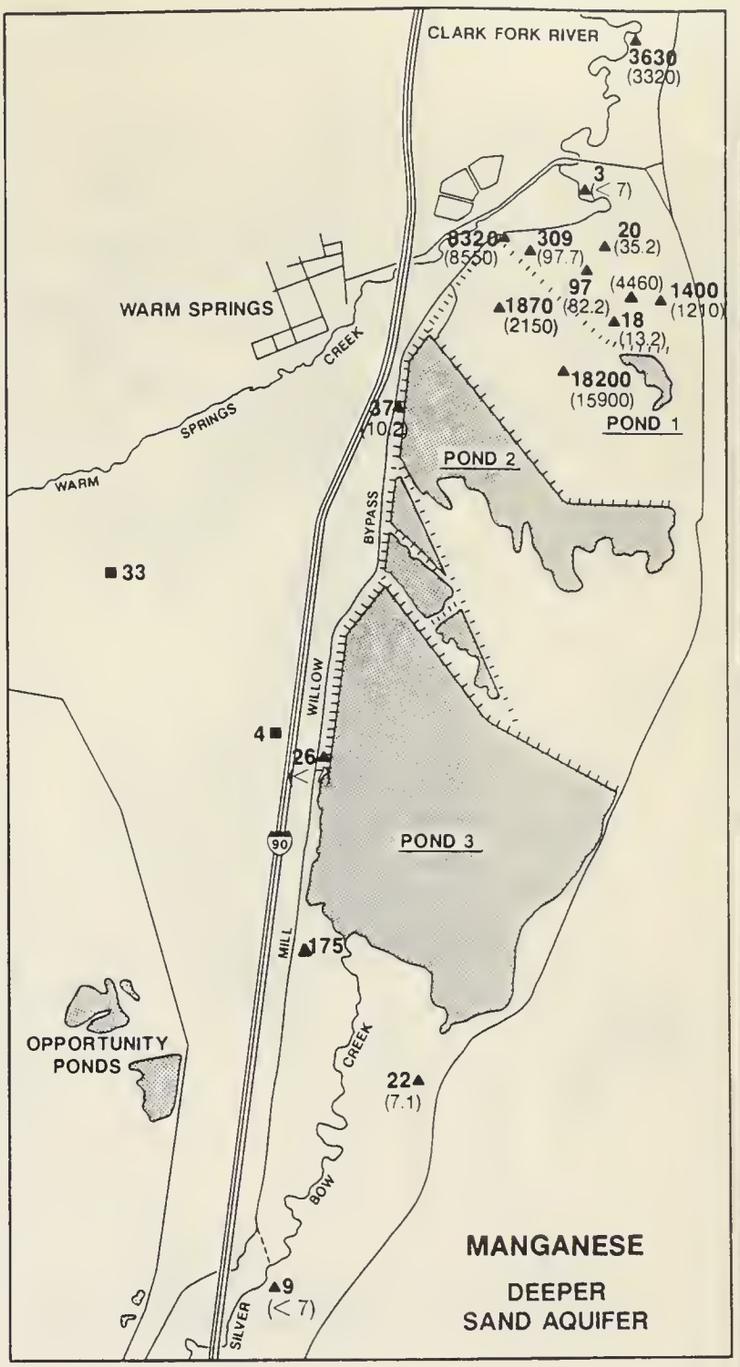
NTS

FIGURE 2-15

CONCENTRATIONS OF DISSOLVED ZINC IN GROUNDWATER (µg/l)
WARM SPRINGS PONDS
FEASIBILITY STUDY

B24856.E2





LEGEND

- ▲ Phase I and II RI Monitoring Wells
- 22 Sampled December 1987 and January 1988
- (7.1) Sampled May, 1988
- ● U.S.G.S. Monitoring Wells Sampled January 1987
- ■ Anaconda Smelter RI Monitoring Wells Sampled October 1985

N

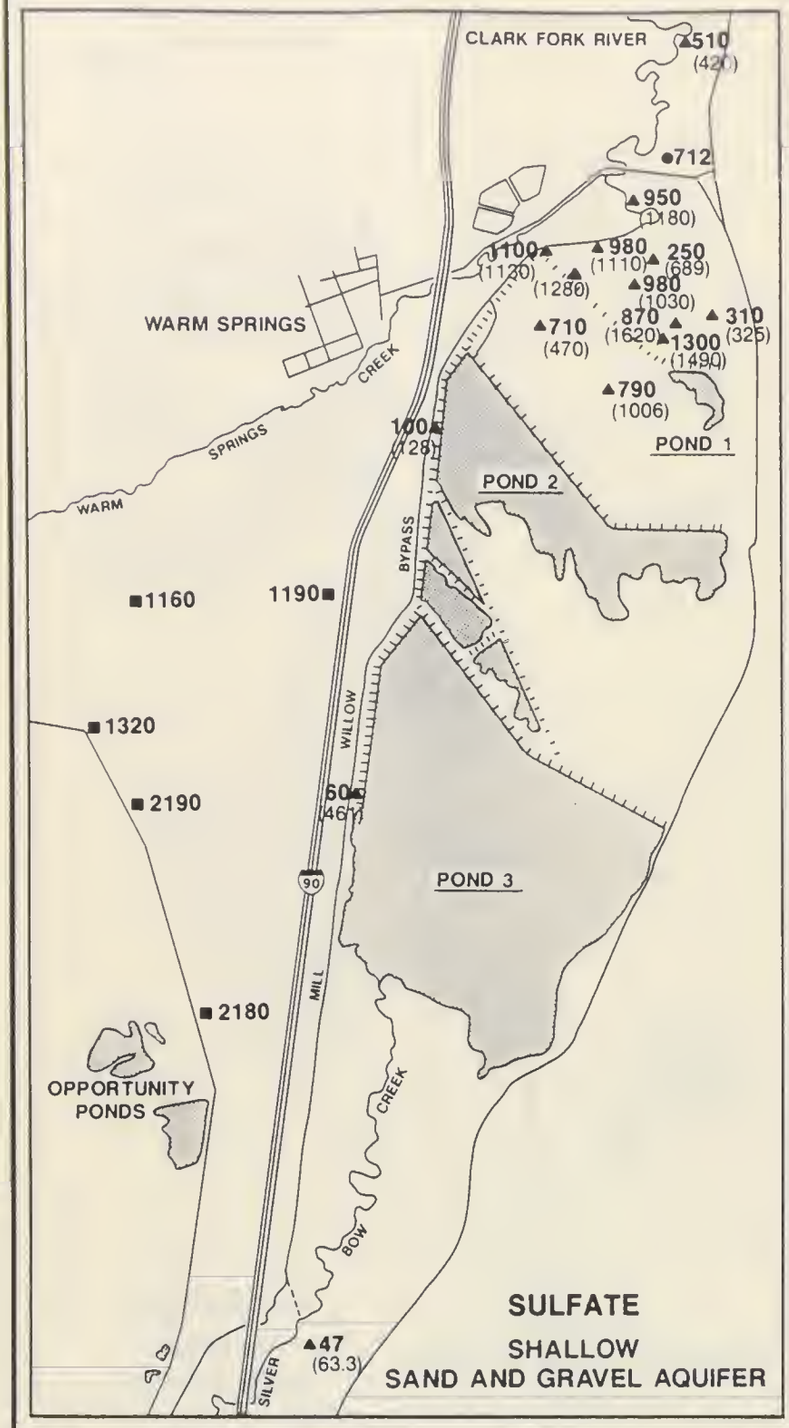
NTS

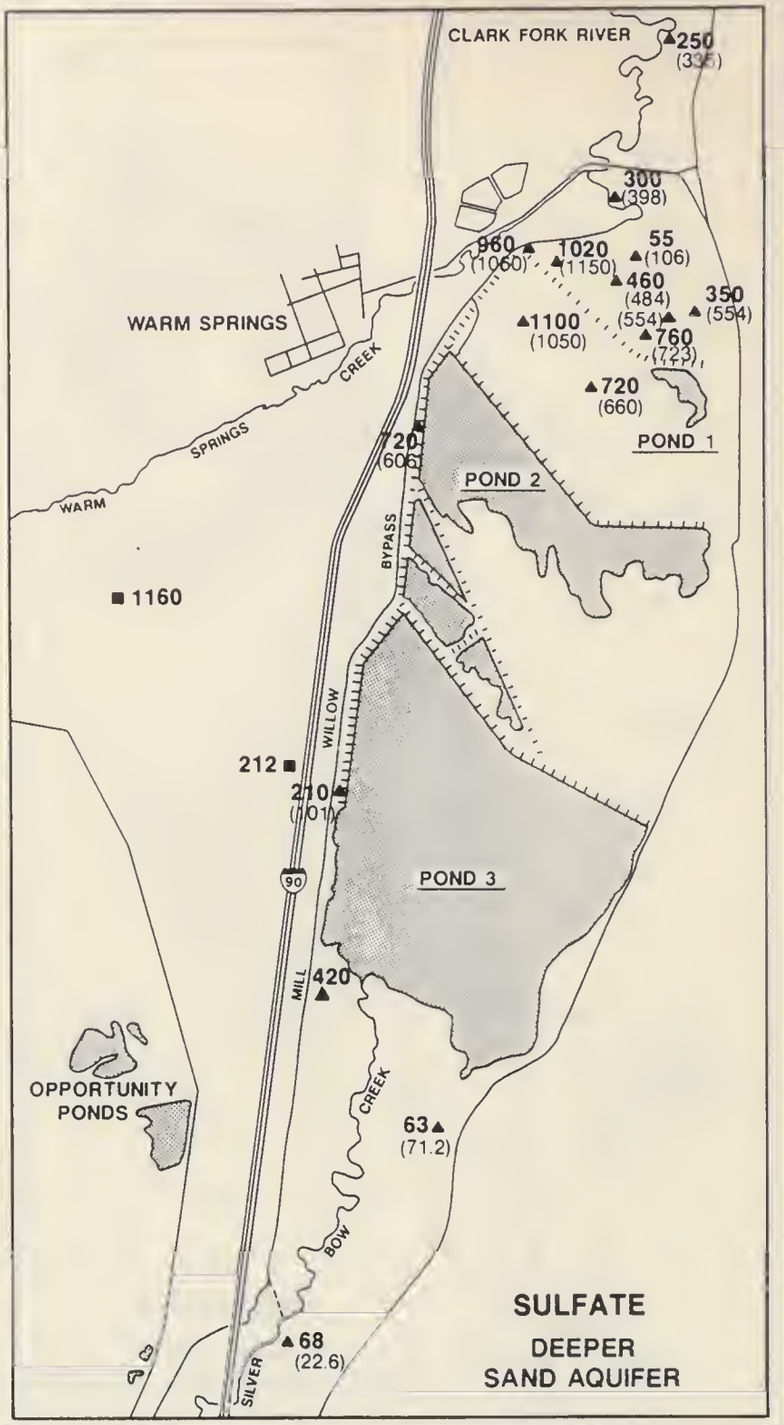
FIGURE 2-16

CONCENTRATIONS OF DISSOLVED MANGANESE IN GROUNDWATER (µg/l)

WARM SPRINGS PONDS
FEASIBILITY STUDY

B24856.E2





LEGEND

- ▲ Phase I and II RI Monitoring Wells
- 63 Sampled December 1987 and January 1988
- (71.2) Sampled May, 1988
- ● U.S.G.S. Monitoring Wells Sampled January 1987
- ■ Anaconda Smelter RI Monitoring Wells Sampled October 1985

N

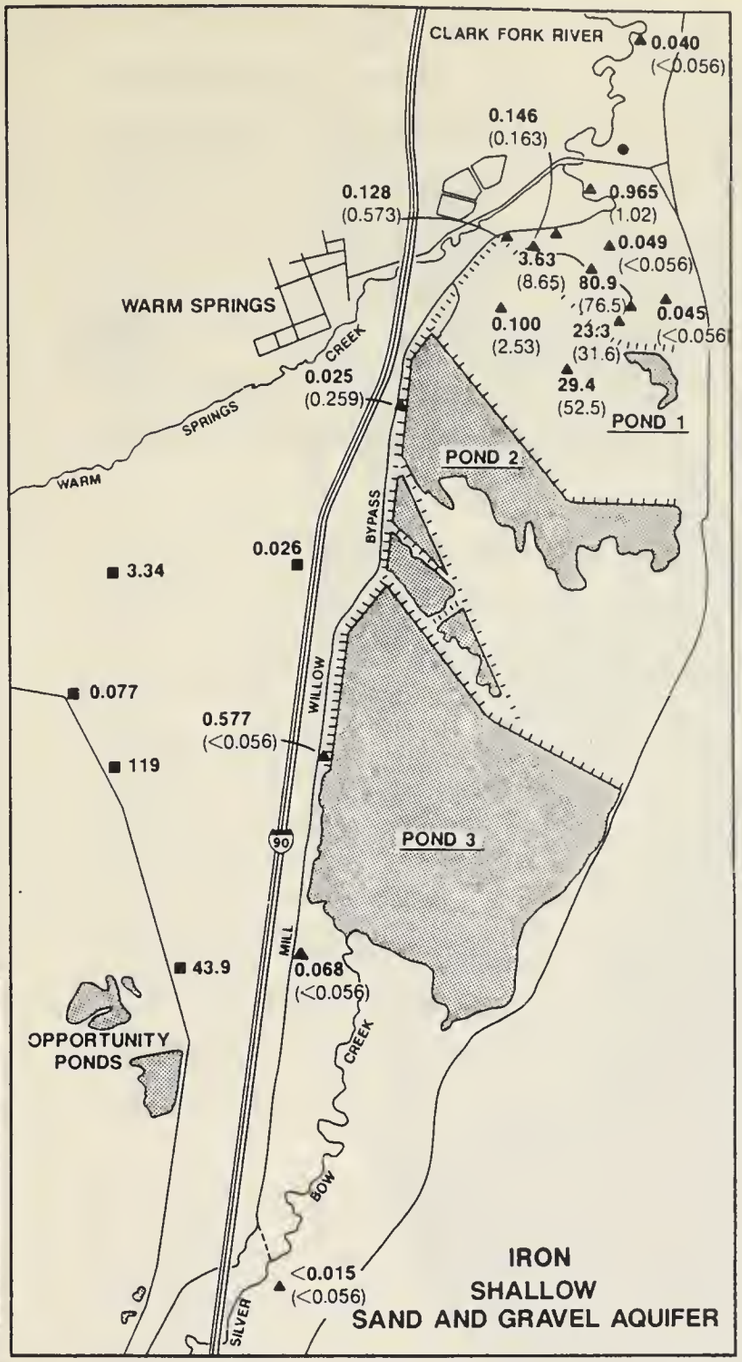
NTS

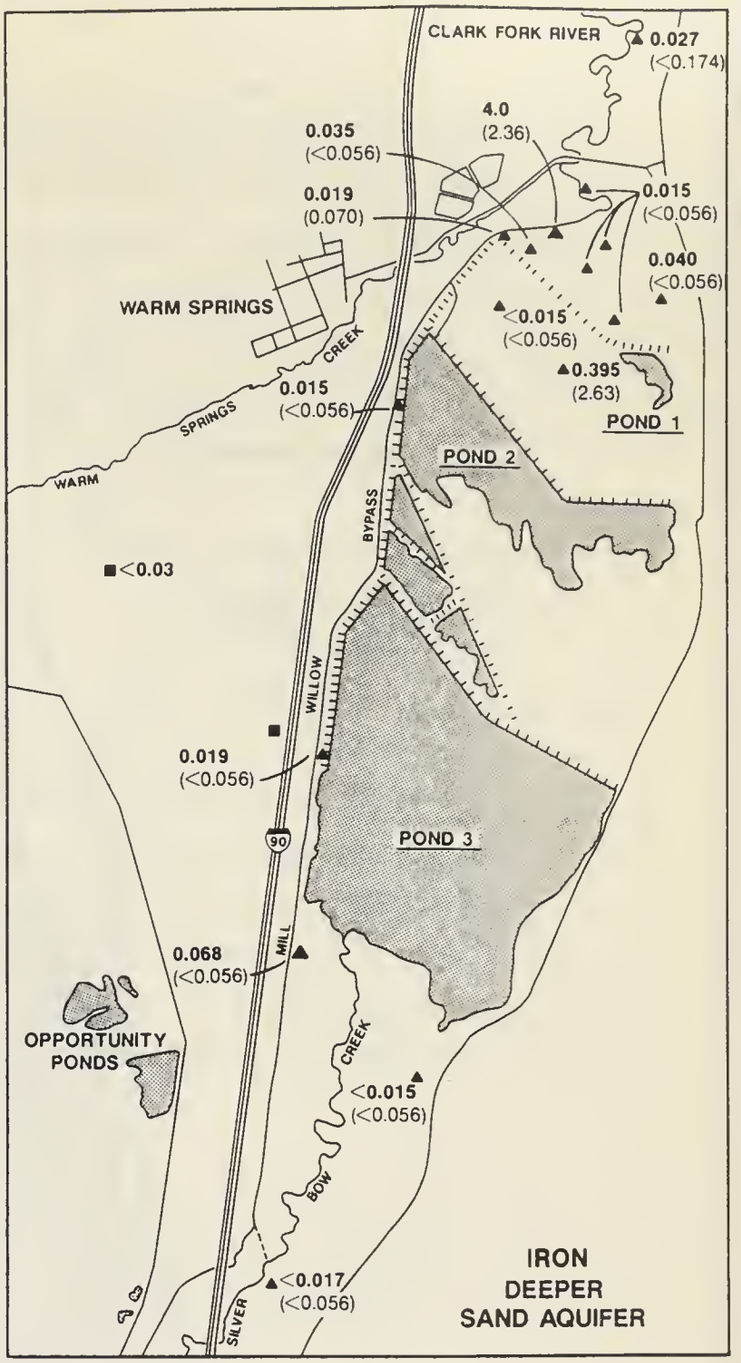
FIGURE 2-17

CONCENTRATIONS OF DISSOLVED SULFATE IN GROUNDWATER (µg/l)

WARM SPRINGS PONDS
FEASIBILITY STUDY

B24856.E2





LEGEND

- ▲ Phase I and II RI Monitoring Wells
- 3.63 Sampled December, 1987 and January, 1988
- (8.65) Sampled May, 1988
- ● U.S.G.S. Monitoring Wells Sampled January, 1988
- ■ Anaconda Smelter RI Monitoring Wells Sampled December, 1985

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FIGURE 2-18

CONCENTRATIONS OF DISSOLVED IRON IN GROUNDWATER (mg/l)

WARM SPRINGS PONDS
FEASIBILITY STUDY

B24856.E2

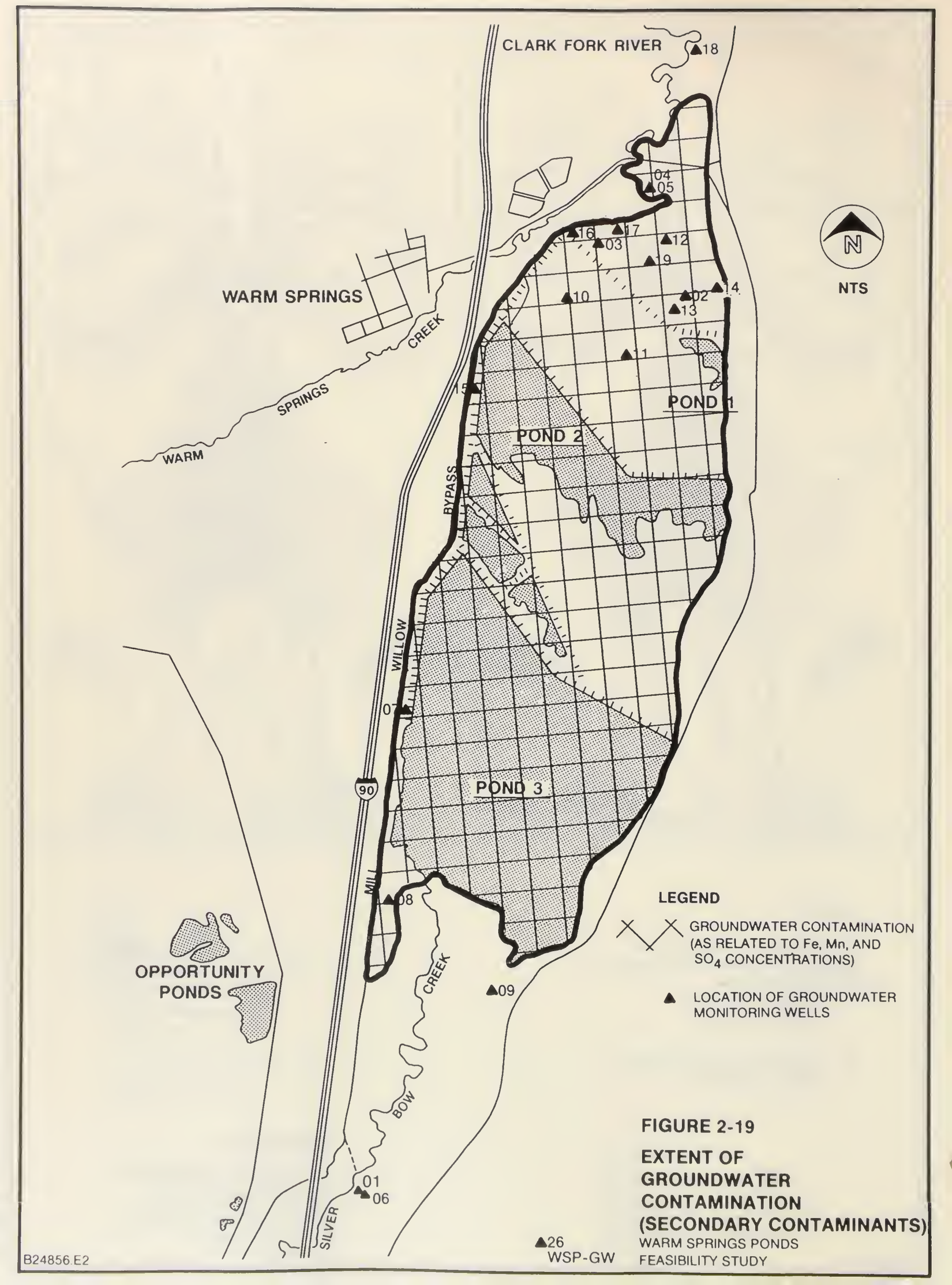

FIGURE 2-19

EXTENT OF GROUNDWATER CONTAMINATION (SECONDARY CONTAMINANTS)

WARM SPRINGS PONDS
FEASIBILITY STUDY

contaminant levels (MCLs) for primary drinking water standards. The sample was obtained from Monitoring Well WSPGW-17 (Figure 2-13) located just north of the northwest corner of Pond 1. This sample contained a cadmium concentration of 11.7 µg/l which is slightly in excess of the standard for cadmium of 10.0 µg/l. The data also indicate groundwater quality generally improves with depth along the course of the bypass channel.

Data obtained from the area west of the Mill-Willow Bypass suggest a separate metals contaminant source (particularly iron, arsenic, and sulfate) in the vicinity of the Opportunity Ponds (Figures 2-14, 2-17, and 2-18). Because the bypass channel acts as a drain for the local groundwater system, it is probable that groundwater contamination in the Opportunity Ponds area affects the quality of water in the Mill-Willow Bypass. The combined inputs of the Opportunity Ponds and Warm Springs Ponds groundwater systems to the Mill-Willow Bypass result in increases of metals loadings along the bypass on the order of 30 percent during baseflow conditions (13 cfs base flow).

On the basis of hydraulic calculations described previously, it appears the majority of seepage into the bypass from groundwater sources occurs in the upper half of the bypass channel in the area adjacent to Ponds 2 and 3.

Groundwater quality downgradient of Pond 1 is generally of poorest quality immediately below the Pond 1 berm; most metals attenuate to the north, or downgradient of the pond system (Figures 2-14, 2-15, and 2-16). Concentrations of most metals also decrease with depth. Highest concentrations of metals are generally associated with the shallow sand and gravel aquifer in the area immediately below the Pond 1 berm.

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Table 2-14 summarizes exceedances of primary and secondary drinking water standards in monitoring wells sampled in the Warm Springs Ponds Operable Unit during the Phase II remedial investigation. Wells exceeding primary standards for arsenic and cadmium include those completed in the shallow sand and gravel aquifer and are primarily located within Pond 1 and downgradient of Pond 1 along the eastern margin of the valley. Figure 2-20 shows the approximate extent of groundwater contamination in the Warm Springs Ponds Operable Unit that exceeds primary drinking water standards for arsenic and cadmium.

Secondary standard exceedances for manganese and iron were measured in wells located adjacent to the Mill-Willow Bypass, within Pond 1, and downgradient of Pond 1. Sulfate is also elevated in the groundwater below Pond 1 with respect to upgradient monitoring wells (Figure 2-17). The highest measured sulfate concentrations are over 1,200 mg/l. Sulfate also appears to decrease in concentration downgradient of the pond system, although the data indicate less change in sulfate concentrations vertically.

Samples were obtained from specially constructed monitoring wells (located upgradient, within, and downgradient of the Warm Springs Ponds) for analyses for Routine Analytical Services target compound list (TCL) organic constituents. The analyses indicate no concentrations above contract required detection limits. The TCL includes analyses for volatile and semivolatile organic compounds in addition to pesticides and PCBs.

As stated previously, groundwater quality generally improves with depth, suggesting groundwater contamination is limited primarily to the shallow sand and gravel aquifer.

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Table 2-14

EXCEEDANCES OF MONTANA PRIMARY AND SECONDARY DRINKING WATER STANDARDS IN GROUNDWATER SAMPLED IN THE WARM SPRINGS PONDS OPERABLE UNIT

Well No.	Number of Samples	Number of Exceedances[a]				
		Primary Standards[b]		Secondary Standards[c]		
		As	Cd	Mn	Fe	SO_4
WSP-GW-02S	2	2	1	2	2	2
WSP-GW-04	2			2		
WSP-GW-05	2	1		2	2	2
WSP-GW-13D	2			2		
WSP-GW-13S	2	1	1	2	2	2
WSP-GW-18S	2	1		1		2
WSP-GW-07S	2			2	1	
WSP-GW-11D	2			2	2	2
WSP-GW-11S	2	1		2	2	2
WSP-GW-17	2		1	2	2	2
WSP-GW-19S	2			2	2	2
WSP-GW-02D	1			1	1	1
WSP-GW-10S	2				1	2
WSP-GW-16S	2			2	1	2
WSP-GW-03D	2			2		2
WSP-GW-03S	2			2		2
WSP-GW-08S	2			1		2
WSP-GW-10D	2			2	2	
WSP-GW-12S	2			2		2
WSP-GW-14D	2			2		2
WSP-GW-14S	2			2		2
WSP-GW-15D	2			2		
WSP-GW-15S	2			2		
WSP-GW-19D	2			2	2	
WSP-GW-16D	2			2		2
WSP-GW-18D	2			2		2

[a]Based on dissolved concentrations.

[b]Montana Groundwater Regulations, ARM 16.20.1003(4), incorporating ARM 16.20.203, which sets forth primary MCLs. Does not include naturally occurring fluoride exceedances. Fluoride exceedances are described in CH2M HILL, 1989.

[c]EPA National Secondary Drinking Water Regulations, 40 CFR Part 143.

Note: Well locations shown on Figure 2-13.
Source: CH2M HILL, 1989.

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Manganese, for example, averages 13,455 ug/l in the shallow aquifer and 440 ug/l in the deeper aquifer. Calculations of groundwater input from the area below Pond 1 to the Clark Fork River indicate the groundwater system contributes very little loading to the river because of the relatively low permeability and low gradient exhibited by the shallow aquifer. Under average conditions, the flow in the Clark Fork River is approximately 137 cfs, while the estimated groundwater input is approximately 1.0 cfs.

AIR

The air is not generally one of the contaminated media for this feasibility study, but it is a pathway for exposure to the tailings deposits and contaminated soils during periods of strong winds.

Dust and sand were observed blowing from tailings deposits areas between Ponds 2 and 3, from the western two-thirds of Pond 1, from tailings deposits areas in the southern portion of Pond 3, and from areas below Pond 1 on at least four occasions during summer months in 1985 and 1986.[33] Prevailing winds at the site average 6 to 8 knots in velocity and are generally from the south (Figure 2-21).

Modeling of the potential impacts from air-entrained particulates was conducted as part of the Public Health and Environmental Assessment (see Appendix A).

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[33] Northern Engineering and Testing, staff observations.

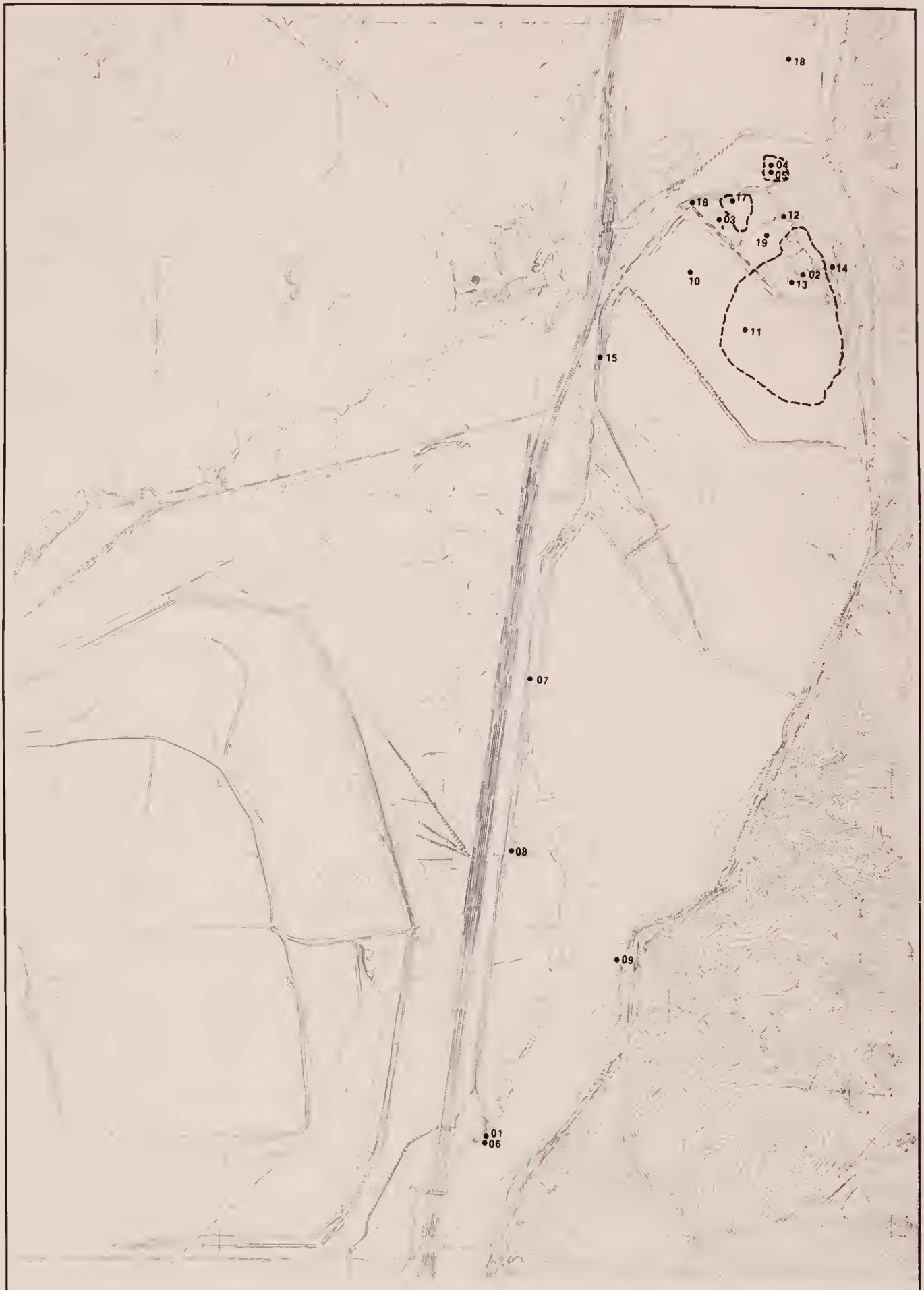

FIGURE 2-20

EXTENT OF GROUNDWATER EXCEEDING PRIMARY MCL FOR CADMIUM AND ARSENIC

WARM SPRINGS PONDS
FEASIBILITY STUDY

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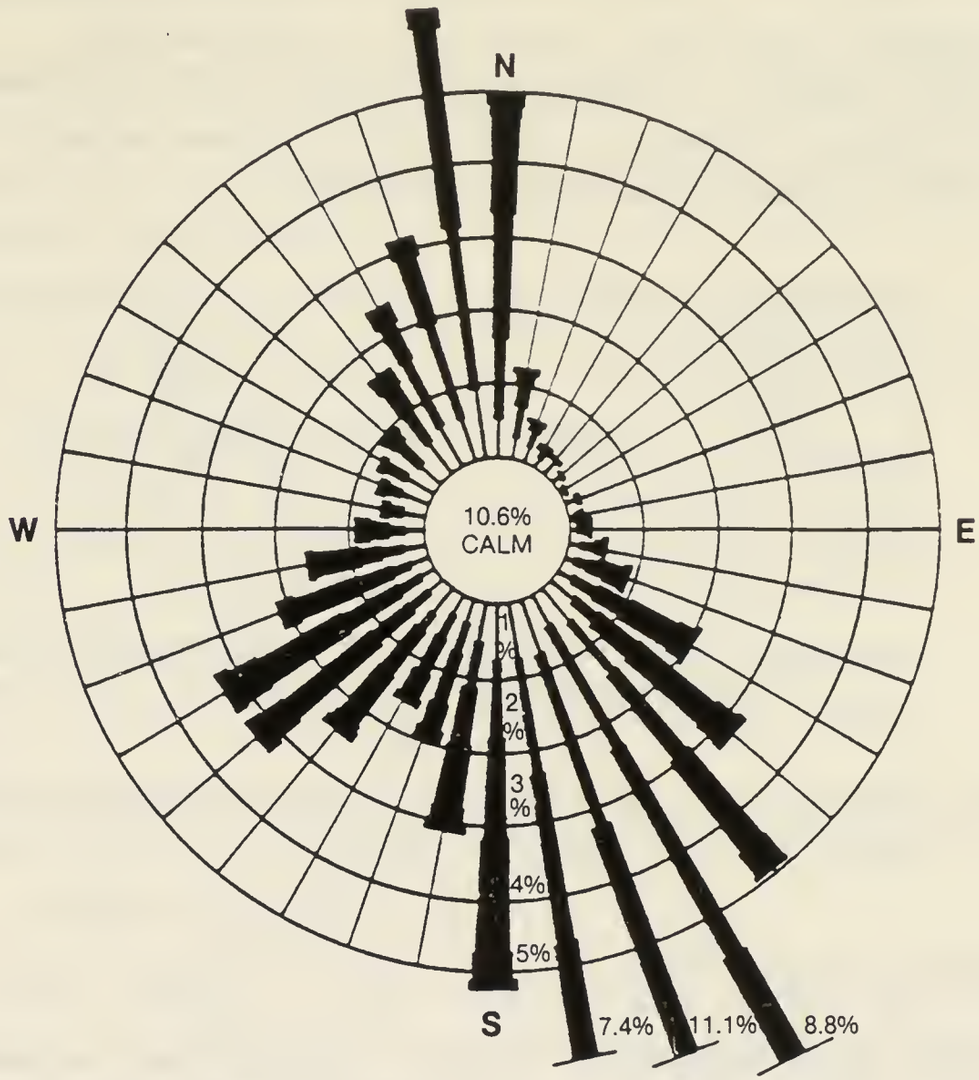

KEY

1-3 KNOTS
3-6 KNOTS
6-10 KNOTS
10-16 KNOTS
16-21 KNOTS
GREATER THAN 21 KNOTS

NOTE: 1 KNOT =1.15 MPH

RADIAL LENGTH IS PERCENT
OF TOTAL OBSERVATIONS

SOURCE:
AMC INTERNAL DATA

FIGURE 2-21

WIND SPEED AND DIRECTION AT OPPORTUNITY PONDS, 1984
WARM SPRINGS PONDS
FEASIBILITY STUDY

B24856.E2

PREVIOUS STUDIES OF REMEDIAL ACTIONS

Previous studies of remedial actions at the Warm Springs Ponds Operable Unit were completed by International Engineering Company[34] (IECO) and Hydrometrics[35] for the Anaconda Minerals Company. IECO completed geotechnical and hydrologic studies of the pond system to:

- Evaluate the existing condition of the embankments and structures
- Determine the potential for flooding and the abilities of the ponds and structures to pass standard design floods
- Recommend modifications that would improve the safety of the tailings ponds
- Develop conceptual designs for developed modifications

Recommendations presented by IECO included the following:

1. Provide for control of seepage and improve the stability of two sections of the existing embankments by constructing toe berms

2. Enlarge and extend the embankment along the Mill-Willow Bypass channel to prevent overtopping of the dams by potential floods from Silver Bow Creek

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[34] International Engineering Company (IECO), 1981. Geotechnical and Hydrologic Studies, Warm Springs Tailings Ponds, Anaconda, Montana. Prepared for Anaconda Copper Company, Denver.

[35] Hydrometrics, 1983.

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3. Excavate emergency spillways in dams that form Ponds 1, 2, and 3 to protect the embankments from overtopping by floods entering from the east

4. Install erosion protection along the bypass channel

5. Institute a periodic program for monitoring water levels in the berms

Hydrometrics completed an evaluation of rehabilitation options for the Warm Springs Ponds. Four options for future use of the pond system were presented:

1. Continue present pond operation
2. Remove tailings and sediment and revegetate
3. Drain the ponds and revegetate
4. Drain the ponds and apply a gravel mulch

Hydrometrics recommended to continue to operate the ponds as they have been and consider implementation of dike modifications recommended by IECO.

Most of the remedial actions recommended in the IECO and Hydrometrics reports have not been implemented at the Warm Springs Ponds, though some work was done in 1987 to extend the Pond 3 berm to keep floods out of that pond.

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Chapter 3
SUMMARY OF THE APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS, AND THE PUBLIC HEALTH AND ENVIRONMENTAL ASSESSMENT

INTRODUCTION

This chapter presents a brief summary of the applicable or relevant and appropriate requirements ("ARARs") and the Public Health and Environmental Assessment (PHEA) for the Warm Springs Ponds Operable Unit. The ARARs summary consolidates state and federal ARARs by identifying only those that are most stringent, thereby avoiding unnecessary duplication. For a more detailed presentation of the PHEA and a complete listing of state and federal ARARs, see Appendixes A and B, respectively.

APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

DEFINITIONS

The cornerstone of remedial actions undertaken pursuant to the Superfund program lies in the satisfaction of applicable or relevant and appropriate state and federal requirements.[1] ARARs are the basic standards by which all aspects of hazardous substance, pollutant, and contaminant cleanup is measured. With only a few exceptions, ARARs

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[1] When ARARs do not exist for a particular chemical or when the existing ARARs are not protective of human health or the environment, pertinent advisories or guidance issued by federal or state agencies should also be considered. United States Environmental Protection Agency (USEPA), 1988a. Draft Guidance CERCLA Compliance With Other Laws Manual. Washington, DC. 1-59.

serve as a floor below which cleanup standards may not fall. They are "threshold criteria."[2] Accordingly, remedial action alternatives developed in this feasibility study are presented in relation to whether they satisfy ARARs.

A distinction exists between "applicable" requirements, and those that are "relevant and appropriate." "Applicable" requirements are those federal requirements, or if state law is more stringent, state requirements that would legally apply at the site regardless of the CERCLA action. "Relevant and appropriate" requirements are those requirements that are not applicable, but address situations or problems sufficiently similar to those at the site and, therefore, are well suited for use at the site.[3] For example, a requirement would be "relevant and appropriate" rather than "applicable" if a jurisdictional restriction, such as the effective date of a statute, precluded the statute from applying. Despite falling outside the technical time bar, the statute, nonetheless, would provide a "relevant and appropriate" standard for the purposes of Superfund cleanup.

Both applicable, as well as relevant and appropriate, requirements are adopted on a site-by-site basis.[4] Identification of "applicable" requirements is based on an objective standard. Greater flexibility exists in identifying "relevant and appropriate" requirements, based on the lead

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2 USEPA, 1988b. Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA, (Interim Final, October 1988). 6-5.

3 CERCLA § 121(d)(2)(A), 42 USC 9621(d)(2)(A); 40 CFR 300.6 (1985). See also Memorandum on CERCLA Compliance with Other Laws, 50 Fed. Reg. 47,946, 47,947 (Nov. 20, 1985); and USEPA, 1988a. 1-10.

4 50 Fed. Reg. 47,918 (Nov. 20, 1985).

agency's (State of Montana's) best professional judgment.[5]

Attainment of both "applicable" as well as "relevant and appropriate" standards is equally mandatory under the Superfund program.[6] Therefore, both types of requirements must be accorded the same consideration in the feasibility study. In addition to ARARs, a feasibility study must also identify and incorporate other federal and state "criteria, advisories, and guidance" (also known as "TBCs" or "To Be Considereds") that ensure protection of human health and the environment and are appropriate for site circumstances.[7]

To the extent possible and appropriate, the remedial action alternatives developed in this feasibility study fall into one of the following five categories required by federal regulation:

- Alternatives for treatment or disposal at an off-site facility
- Alternatives that attain ARARs
- Alternatives that exceed ARARs
- Alternatives that do not attain ARARs but will reduce the likelihood of present or future threat from the hazardous substances and provide

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5 Id. 47,919. See also USEPA, 1988a. 1-10.

6 CERCLA § 121(d)(2)(A), 42 USC § 9621 (d)(2)(A); 50 Fed. Reg. 47,918 (1985). See also USEPA, 1988a. 1-11.

7 CERCLA § 121(d) (2) (A), 42 USC 9621(d) (2) (A); 40 CFR 300.68(i)(4) (1985).

significant protection to public health, welfare, and the environment; alternatives under this category will closely approach the level of protection provided by ARARs

- A no-action alternative [8]

The detailed analysis of alternatives, contained in Chapter 8 of this feasibility study, describes how each alternative complies with ARARs and other identified advisories, criteria, and guidance.[9] Appendix B contains a comprehensive description of all federal and state ARARs for Warm Springs Ponds. Below is a summary of the ARARs most critical to remedy selection at the site, organized by the three ARARs categories (chemical-specific, action-specific, and location-specific).

CHEMICAL-SPECIFIC ARARS

Chemical-specific ARARs include those laws and regulations governing the release to the environment of materials possessing certain chemical or physical characteristics or containing specific chemical compounds. Chemical-specific ARARs generally set health- or risk-based numerical values or methodologies which, when applied to site-specific conditions, result in the establishment of numerical values. These values establish the acceptable amount or concentration of a chemical that may be found in, or discharged to, the ambient environment."[10] If a chemical is subject to

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8 40 CFR 300.68(f)(1) (1985) and Memorandum on CERCLA Compliance with Other Environmental Laws, 50 Fed. Reg. at 47,947 (Nov. 20, 1985).

9 USEPA, 1988b. 6-6.

10 USEPA, 1988a. xiv.

more than one discharge or exposure limit, the more stringent ARAR generally applies.

The most significant Montana chemical-specific ARARs for the operable unit consist of standards protecting the quality of surface and groundwater for human health and environmental purposes. Pertinent regulations promulgated pursuant to the Montana Water Quality Act specify oxygen concentration, pH level, turbidity, and other contaminant levels to prevent, abate, and control pollution of Montana waters, effectuate Montana's nondegradation policy, and protect the present and future most beneficial uses, including recreational, agricultural, wildlife propagation, and other beneficial uses of Silver Bow Creek and the Clark Fork River. Surface waters flowing from the operable unit may not cause exceedances of the following hardness-based limits for ambient water concentrations of toxic or deleterious substances to protect aquatic life:[11]

Constituent	Acute Level (mg/l)	Chronic Level (mg/l)
Cadmium	0.0039	0.0011
Copper	0.018	0.012
Lead	0.082	0.0032
Silver	0.0041	0.00012
Zinc	0.12	0.11

A hardness of 100 mg/l was assumed for these limits. One hundred was the average hardness detected during surface water testing at the operable unit. The following limits apply, as well, for ambient water concentrations of toxic or deleterious substances to protect public health from ingestion of contaminated water and fish:[12]

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[11] ARM 16.20.622(h)(i), incorporating by reference "Gold Book" freshwater acute and chronic levels for water and fish ingestion listed in Update Number Two (5/1/87) of Quality Criteria for Water 1986 (EPA 440/5-86-001).

[12] Ibid.

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Constituent	Water and Fish Ingestion	Fish Consumption Only
Arsenic	2.2 ng/l	17.5 ng/l
Iron	0.3 mg/l	--
Mercury	144.0 ng/l	146.0 ng/l
Selenium	10.0 ug/l	--

The values presented above for arsenic represent a human risk level of 1 x 10^{-6} based on human health criteria for carcinogens.

The point of compliance for ambient surface water standards will be defined by the lead agency in the ROD. It is expected to be just above the confluence of the pond system with Warm Springs Creek. This confluence defines the beginning of the Clark Fork River.

Regulations promulgated pursuant to Montana's Public Water Supply Act govern the quality and potability of public water supplies and domestic uses. These public water supply regulations establish maximum contaminant levels (MCLs) to protect public health for organic and inorganic chemicals, turbidity, and microbiological contamination. They also establish secondary maximum contaminant levels to protect public welfare. Because surface and groundwater within the operable unit is not used presently as a drinking water source, public water supply standards are not applicable. Nonetheless, these standards are relevant and appropriate because, in the future, surface and/or groundwater within the operable unit could be used as a drinking water source.

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The following MCLs apply both to surface water used for drinking and to groundwater:[13]

Constituent	Level (mg/l)
Arsenic	0.05
Cadmium	0.010
Lead	0.05
Nitrate (as N)	10.0
Selenium	0.01

The point of compliance for these surface water and groundwater requirements will be defined in the ROD. It is expected to be just before the confluence of the Mill-Willow Bypass with Warm Springs Creek. The point of compliance for groundwater standards is the waste management unit boundary. Thus, for certain alternatives, the groundwater point of compliance will be at the downstream edges of the ponds. Other alternatives may incorporate a groundwater point of compliance at the downstream edge of wetlands or groundwater treatment trenches.

Any point-source discharges from the operable unit to the Clark Fork River are also subject to the C-2 classification, requiring conformity with State of Montana nondegradation rules and application of the standards listed above for ambient water concentrations (both to protect aquatic life and to protect public health from ingestion of contaminated water and fish) when stream flows equal or exceed the minimum consecutive 7-day average flow, which may be expected to occur on the average of once in 10 years.[14] The point of

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[13] ARM 16.20.203 and 16.20.1003(4).

[14] ARM 16.20.622(h)(ii), incorporating by reference ARM 16.20.631(4).

compliance for these discharges is at the place of discharge from the ponds into what is now the Mill-Willow Bypass.

Chemical-specific ARARs addressing operable unit air quality under Montana's Clear Air Act will also apply during and after site cleanup. These standards will primarily apply to the regulation of site dust generation and include limitations on levels of particulate matter, lead, and air opacity.[15] The point of compliance for opacity requirements lies at the emission source, while the point of compliance for the remaining air quality standards lies at the point of probable human exposure at the site during remedy implementation.[16] Additionally, Montana's Occupational Health Act limits noise levels and air contaminants in the workplace to protect human health and safety, and thus applies onsite during remedy implementation.[17]

Federal ARARs governing water and air quality closely parallel the Montana contaminant-specific standards. Because the state standards are part of delegated or authorized programs under the Clean Water Act, Safe Drinking Water Act, and Clean Air Act, the state standards are considered the more stringent and are identified here as the appropriate requirements.

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15 ARM 16.8.815, -.818, -.821, and -.1401(4).

16 ARM 16.8.1401(4); 40 CFR Parts 50 and 61.

17 ARM 16.42.101 and -.102.

No federal or State of Montana chemical-specific ARARs exist for sediments or soil. Acceptable concentrations of heavy metals in soil and sediments (i.e., concentrations exposure to which will not adversely affect human health) are established in the PHEA (Appendix A) and described later in this chapter. The PHEA identifies the various routes by which humans, flora, and fauna are exposed to soil contamination. It then evaluates the risk to humans presented by a range of contaminant concentrations in the soils.

LOCATION-SPECIFIC ARARS

Location-specific ARARs are restrictions placed on the concentrations of hazardous substances or the conduct of cleanup activities because they are in specific locations. Location-specific ARARs relate to the geographic or physical position of the site, rather than to the nature of the site contaminants.

Because the operable unit is located entirely within the 100-year floodplains of Mill, Willow, and Silver Bow Creeks, and the Clark Fork River, the most significant State of Montana location-specific ARARs regard use of and construction within the floodplain. Specifically, structures built within the floodplain must be constructed on fill material, anchored, and located as far as practicable from stream channels. Furthermore, if a proposed development may significantly increase flood velocities or depths, additional hydraulic and survey information may be required, such as

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valley cross sections of the water course and adjoining floodplain, professional certification that floodproofing measures are reasonably adequate to protect against major flood damage, and documentation of the probable effect on upstream or downstream property owners.[18]

Additionally, certain regulations stipulating flood control measures within the floodway are relevant and appropriate.[19] They require flood control levees and flood walls to safely convey a flood of 100-year frequency and to not increase the elevation of the 100-year frequency beyond one-half foot at any point. Riprap must withstand a flood of 100-year frequency, not increase the elevation of a 100-year flood and not increase erosion. Channelization projects are allowed if they do not significantly increase the magnitude, velocity, or elevation of a 100-year flood downstream from the project.

Floodplain management in Montana also is governed by the Natural Streambed and Land Preservation Act of 1975, enacted to ensure the protection of streams and streambeds. Accordingly, the alternatives for remediation must attempt to reduce disturbance to the stream channel, fish, and aquatic habitat, minimize soil erosion, sedimentation, and turbidity, and avoid creating harmful flooding or erosion problems upstream or downstream.[20] Because these requirements are not duplicated by federal law, these state standards are determined to be the more stringent and therefore are appropriate ARARs for the operable unit.

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18 ARM 36.15.801.

19 ARM 36.15.606.

20 MCA § 75-7-102; ARM 36.2.404.

In addition to these Montana location-specific ARARs, federal location-specific ARARs apply to Warm Springs Ponds remedial activities. Compliance with the National Historic Preservation Act and Archaeological and Historic Preservation Act requires the identification of any cultural resources and any scientific, prehistoric, or archaeological artifacts at Warm Springs Ponds. The operable unit includes two sites (the ponds plus an arched concrete bridge) that are eligible for inclusion in the National Register of Historic Places. Effects of remedial activities on these resources must be assessed. Preservation of these resources may be required and, at a minimum, measures to minimize or mitigate any adverse effects on the resources must be incorporated into the proposed remedial activities.

Because a pair of bald eagles is known to feed within the boundaries of the operable unit, the Endangered Species Act applies. Under this law, any proposed remediation must be assessed to determine its impact on the endangered species, and, if an adverse effect is likely to occur, other alternatives must be selected, mitigative activities recommended, or an exemption documented. The federal Fish and Wildlife Coordination Act also applies, precluding any modification of any stream or other water body as a result of remedial activities unless the modification provides for adequate protection of fish and wildlife resources. Finally, protection of wetlands is required by federal executive order, and remedial activities must consider measures to mitigate adverse impacts to these resources.

ACTION-SPECIFIC ARARS

Action-specific ARARs are usually technology- or activity-based requirements or limitations on actions taken with respect to hazardous wastes. A particular remedial activity will trigger an action-specific ARAR. Unlike chemical-specific and location-specific ARARs, action-specific ARARs do not in themselves determine the remedial alternative. Rather, action-specific ARARs indicate how the remedy, once selected, must be achieved.[21] The most significant action-specific ARARs at the operable unit relate to dam safety, hazardous waste management, land reclamation, and discharge of dredged or fill material into Silver Bow, Mill, and Willow Creeks, and the Clark Fork River.

The Montana Department of Natural Resources and Conservation regulations relating to dam safety are central to remedial action at the operable unit. The Warm Springs Ponds dams are classified as high-hazard dams. Consequently, based on the storage capacity and height of these high-hazard dams, Warm Springs Pond 3 must be constructed to withstand one-half of the probable maximum flood; Pond 2 must withstand 0.3 of the probable maximum flood; and Pond 1 must withstand 0.2 of the probable maximum flood.[22] Based on the direction of the State of Montana, the engineer has sized the alternatives using these levels of inflow floods for the three ponds.

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21 USEPA, 1988a. 1-29.

22 ARM 36.14.502.

Other action-specific ARARs pertinent for high-hazard dams include design safeguards protecting the dam's embankment, foundation, and abutments against internal erosion; against overtopping by wave action; against erosion of upstream and downstream slopes; and to ensure that the most severe earthquake reasonably anticipated would not cause catastrophic failure and loss of life.[23] All dams must have an adequate seepage monitoring and collection system.[24] Because these requirements are not duplicated by federal laws, the state standards are the most stringent and are appropriate for this site.

The Montana Hazardous Waste Act is another source of action-specific ARARs at Warm Springs Ponds. This Act imposes proper treatment, storage, transportation, and disposal requirements for hazardous wastes, as well as for the siting, design, operation, maintenance, monitoring, inspection, closure, and post-closure of hazardous waste management facilities.[25]

Because various alternatives discussed in the feasibility study propose discontinuing the use of Ponds 1, 2, and 3 or portions of them, certain provisions of the hazardous waste closure and post-closure requirements apply.[26] Two general closure options exist: 1) clean closure, and

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23 ARM 36.14.501.

24 Id.

25 MCA 75-10-405. Title 75, Chapter 10, Part 4.

26 Montana has incorporated, by reference, federal closure and post-closure requirements for hazardous waste management facilities. ARM 16.44.702. Complete citations to the authorities setting forth these hazardous waste management requirements are contained in Appendix B, which lists all state and federal ARARs for the operable unit. Because the state standards exist as part of a delegated program under the Resource Conservation and Recovery Act (RCRA), as amended, the state standards are deemed the more stringent for use at this site.

2) landfill closure. Under the clean closure option, soils and sediments must be removed from the ponds and surrounding areas, such that drinkable leachate and edible soils remain (that may be safely consumed). Under the landfill closure option, regulations require proper isolation of contaminated materials by capping or covering contamination with clean soil, revegetation, and post-closure maintenance. Prior to capping the waste, free liquids must be removed from the waste, and the remaining solids must be stabilized and consolidated. Remaining wastes must be covered with a cap designed to provide long-term minimization of the migration of liquids through the waste, function with minimum maintenance, promote drainage, minimize erosion, and accommodate settling to maintain the integrity of the cover. Closure and post-closure requirements, which should be considered in designing an adequate operations and maintenance program, include groundwater monitoring, financial assurances, periodic inspections, ongoing maintenance, use restrictions, and deed notices. Because of the unique nature of the site, many of the RCRA closure requirements may be appropriate to any remedial action that would close one or more of the ponds with waste left in place.[27]

Other alternatives discussed in the feasibility study propose continuing the operation of Ponds 2 and/or 3, or establishing alternative onsite hazardous waste management facilities to trap and dispose of hazardous substances, pollutants, and contaminants. These alternatives must comply with action-specific ARARs for surface impoundments, particularly those requiring structural integrity to prevent massive failure.

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[27] USEPA, 1988a. 2-19 to 2-21.

All nonliquid waste materials within the Warm Springs Ponds Operable Unit not subject to the Montana Hazardous Waste Act are subject to the Montana Solid Waste Management Act. Regulations under that law prohibit locating solid waste disposal sites in a 100-year floodplain and in places that will cause pollution of surface or groundwater and require installation of drainage structures to divert surface waters from entering disposal areas.[28]

Montana's reclamation statutes pertaining to surface mining provide another set of significant action-specific ARARs and will be imposed for all remedial action alternatives presented in this study. Reclamation of lands disturbed by mining requires grading, backfilling, subsidence stabilization, water control, topsoiling, revegetation, and other measures necessary to eliminate damage from soil erosion, subsidence, land slides, water pollution, and hazards to life and property.[29] Pertinent regulations govern backfilling and grading (to minimize erosion, instability, and adverse effects on groundwater, plant growth, and land uses); hydrology (to ensure stability of the reclaimed area, as well as the quality of ground and surface water); topsoiling and revegetation (to establish a diverse, effective, and permanent vegetative cover); and protection of wildlife and air resources.[30]

Together with public health and environmental protectiveness standards (as described in the PHEA), which establish acceptable soil concentration levels for arsenic and lead, reclamation laws provide for the consolidation, removal, or capping

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28 ARM 16.14.505.

29 MCA § 82-4-231.

30 ARM Title 26, Chapter 4, Subchapters 5-7 and 11.

of soils and sediments, at a minimum, to achieve acceptable concentration levels. Following consolidation, removal, or capping, regrading and a soil cover of at least 18 inches is required to provide an adequate medium for vegetation.[31] Revegetation then demands establishing a diverse, effective, and permanent vegetative cover of the same seasonal variety as that native to the area, which is capable of self-regeneration and plant succession.[32] The success of revegetation is measured on the basis of unmined reference areas, or control areas, which indicate the natural production representative of the area.

In areas already vegetated, even if only partially, the adequacy of the vegetative cover also will be measured against the unmined reference areas. If the cover is adequate, no further reclamation need be undertaken. If inadequate, the area must be tested, as described above, for arsenic and lead concentrations, soils and associated contamination may need to be removed to ensure adequate health and environmental protection, and a soil cover, regrading, and revegetation will be required.

If remedial activities involve the discharge of dredged or fill material into Silver Bow, Mill, or Willow Creeks, or the Clark Fork River, Section 404 of the Clean Water Act applies. Regulations promulgated pursuant to this section are intended to ensure that discharges of dredged or fill material will not have an unacceptable adverse effect on municipal water supplies, shellfish beds and fishery areas, wildlife, or recreational areas. Likewise, the Montana

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31 See USEPA's action-specific ARARs regarding revegetation, Appendix B, citing the Surface Mining Control and Reclamation Act.

32 MCA § 82-4-233, ARM 26.4.711.

Water Quality Act, Public Water Supplies Act, and Montana Groundwater Act, and regulations promulgated thereunder, contain action-specific requirements for discharges into state waters and for water wells intended for public consumption, including requirements for water monitoring, sample collection, and analysis.

Finally, other action-specific ARARs identified in Appendix B concern mechanisms for ensuring occupational safety under the Montana Safety Act and the Employee and Community Hazardous Chemical Information Act and for governing the use, diversion, and appropriation of surface and groundwater, where such requirements impact environmental quality, pursuant to the Montana Water Development Program Act, Natural Streambed and Land Preservation Act of 1975, and others.

WAIVERS

Federal law recognizes there may be instances in which ARARs cannot be met with respect to remedial actions onsite. It, therefore, identifies six circumstances under which ARARs may be waived. However, other statutory requirements, specifically, the requirement that remedies be protective of human health and the environment, cannot be waived.[33] Waivers occur as the exception, not the rule.[34] Waivers are appropriate if:

- The remedial action selected is an interim remedy and only part of a total remedial action that will attain ARARs when completed.

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[33] USEPA, 1988a. 1-71.

[34] 50 Fed. Reg. 47,921 (1985).

- Compliance with ARARs at the site would result in greater risk to human health and the environment than alternative options.

- Compliance with ARARs is impracticable, from a technical perspective.

- The remedial actions selected will attain an equivalent standard of performance, although ARARs are not met.

- With respect to state ARARs, the State has inconsistently applied ARARs in similar circumstances at other remedial actions within the State.

- In the case of fund-financed remedial actions, financial restrictions within the Superfund program require fund-balancing such that satisfaction of ARARs at the site must give way to a greater need for protection of public health and welfare and the environment at other sites.[35]

Chapter 8 of this feasibility study, which provides a detailed analysis of the remedial action alternatives, identifies how each alternative complies with ARARs. If an ARAR would not be satisfied, the detailed analysis notes that a waiver may be required. The Record of Decision, which will detail the remedy selected, will document the reasons for waiving any ARAR.[36]

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[35] CERCLA 121(d)(4), 42 USC 9621(d)(4), 40 CFR 300.68(i)(5) (1985). See also USEPA, 1988a, 1-71 through 1-75.

[36] See USEPA, 1988a, Exhibit 1-4 at 1-58.

PUBLIC HEALTH AND ENVIRONMENTAL ASSESSMENT SUMMARY

The following sections present a summary of the Public Health and Environmental Assessment (PHEA). (Refer to Appendix A for specific assumptions and details of the assessment.)

INTRODUCTION

A public health and environmental assessment is conducted to determine the potential threat to human health and the environment as a result of contamination at the site in absence of any remedial action undertaken by the State of Montana or the USEPA. The no-action alternative, as defined for this assessment, is one where current operations at the site continue unchanged (e.g., periodic liming of incoming surface water from Silver Bow Creek, pump-back of groundwater discharge from below Pond 1 and activities related to the management of the wildlife area by the state), but nothing would be done to remediate the contamination present in the ponds nor prevent releases from the ponds.

This assessment is required by CERCLA and the NCP and has been conducted according to guidelines developed by the USEPA.[37,38,39]

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[37] USEPA, 1986a. Superfund Public Health Evaluation Manual. EPA 540/1-86-060, Office of Emergency and Remedial Response, Washington, DC.

[38] USEPA, 1986b. Guidelines for the Health Risk Assessment of Chemical Mixtures, 51 Fed. Reg. 34, 014-34, 025(1985).

[39] USEPA, 1986c. Guidelines for Carcinogenic Risk Assessment. 51 Fed. Reg. 33, 991-34, 003(1985).

SITE SETTING

"The site" referred to throughout this chapter is that area shown on Figure ES-1 of the Executive Summary. Chapter 2 of this report presents the site background and a description of the site. (Refer to Appendix A for greater detail.)

The area surrounding the site is rural, with two small towns and a few scattered ranches. Approximately 300 persons reside within Warm Springs, the town adjacent to the northwest edge of the site. Opportunity, the other small town near the site is to the southwest, with a population of about 750 persons. Between these two towns is a small development, called the Highway 48 development, with 10 to 15 homes and 50 residents. East of the site, a bluff sharply alters the topography of the flat ponds. Several ranches are located on the bluff and about 30 persons live at these ranches.[40,41] Figure 3-1 shows the surrounding towns and residences in relation to the site.

The area has a semi-arid continental climate with most of the precipitation occurring in the form of snow. Snow usually covers the site from November through March or early April. Therefore, snow is present approximately 150 days per year. Winds in the area are predominantly (more than 40 percent) out of the south/southeast and blow toward the north/northwest, as depicted on Figure 3-1.

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[40] Manning, Milo, 1988. Deer Lodge County Planning Supervisor, Anaconda, Montana. Personal communication.

[41] Strazdas, Maureen, 1988. Montana State Census and Economic Information Center, Helena, Montana. Personal communication.

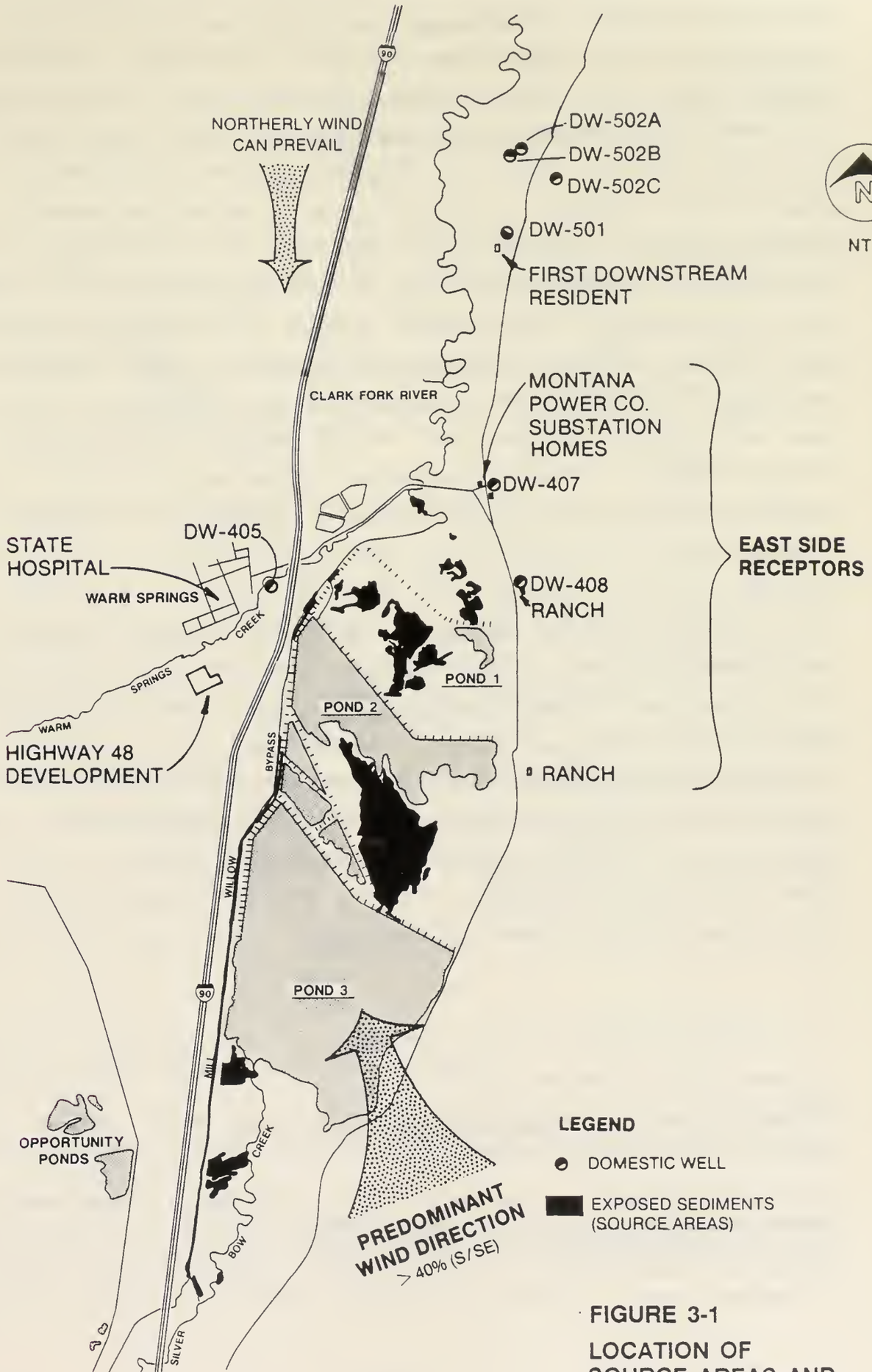

FIGURE 3-1

LOCATION OF SOURCE AREAS AND RECEPTORS

WARM SPRINGS PONDS
FEASIBILITY STUDY

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The site is within the floodplain of Mill, Willow, and Silver Bow Creeks. Flooding and high creek flows occur primarily in May and June, those months with high rainfall coupled with snow melt at higher elevations. Flows during a 100-year flood (4,000 cfs peak flow in Silver Bow Creek) and the limits of the 100-year floodplain have been determined.[42,43] (Figure 4-2 of Chapter 4 shows the extent of the 100-year floodplain at the site.) A 100-year flood would have a high probability of causing erosion of Pond 2 and Pond 1 dikes. This could result in failure of one or more dikes, and the downstream movement of pond sediment and tailings.[44] The probable maximum flood (PMF) has also been estimated for the site. A PMF of 146,000 cfs peak flow is more than an order-of-magnitude greater than the 100-year flood event and could breach all three dikes of the pond system.

The site is owned by Atlantic Richfield Company, which merged with Anaconda Minerals Company (AMC) in 1977, and is maintained as a Wildlife Management Area administered by the Montana Department of Fish, Wildlife and Parks (MDFWP) in association with ARCO. Management activities include maintenance of inflow/outflow structures, waterfowl enhancement (planting grain, habitat improvement, etc.), fish stocking (brown trout for catch-and-release only), and monitoring wildlife use of the area. The site is attractive

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42 CH2M HILL, 1988. Silver Bow Creek Flood Modeling Study. State of Montana, Department of Health and Environmental Sciences, Helena, Montana.

43 International Engineering Company (IECO), 1981. Geotechnical and Hydrologic Studies, Warm Springs Tailing Ponds, Anaconda, Montana. Prepared for Anaconda Copper Company, Denver, Colorado.

44 CH2M HILL, 1988.

to wildlife, particularly to waterfowl and other birds. The site has produced osprey young in past years and a pair of immature bald eagles have built a nest 2 years in a row at the site but have not produced young. The bald eagle is the only federally listed threatened and endangered species known to occur at the site.[45,46]

Mammals present at the site are those typical of the scrubby habitat (see Appendix A Figure 2-4 for a depiction of the vegetation types at the site). These include mule deer, white-tailed deer, fox, coyote, badger, muskrat, rabbit, beaver and mice. Ground squirrels have recently (within the last 3 years) been sited within the pond boundaries.[47]

The fishery of the ponds is classified as a high priority resource.[48] The species present in each pond depend on the pond depth and food sources. The Wildlife Ponds support the largest brown and rainbow trout (10 to 12 pounds) of the pond system. The ponds are designated as only catch-and-release by the Montana Fish and Game Commission.

The PHEA (Appendix A) presents a complete listing of bird, mammal and fish species found in the area.

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[45] Gallager, Jerry, 1988. Montana State Department of Fish, Wildlife and Parks, Area Manager, Warm Springs, Montana. Personal communication.

[46] Wood, G., 1988. Fish and Wildlife Services, Ecological Services, Bozeman, Montana. Personal communication.

[47] Gallager, 1988.

[48] MultiTech, 1986. Fish Tissue Investigation. Silver Bow Creek Remedial Investigation, Draft Final Report. State of Montana, Solid and Hazardous Waste Bureau, Department of Health and Environmental Sciences, Helena, Montana.

NATURE AND EXTENT OF CONTAMINATION

Chapter 2 describes the nature and extent of contamination at the site. Site investigations to date indicate inorganic constituents in groundwater (particularly shallow groundwater immediately downgradient of Pond 1), surface water (although contaminant concentrations decrease in pond outflow as compared to inflow from Silver Bow Creek), sediments and exposed tailings, and biological tissue (liver only) at concentrations above background level. No data have been collected to establish contaminants in the air.

Data summaries for each media were prepared for the PHEA. These summaries provide information on the maximum concentration of a contaminant in a media at a specific sampling point or a general location (grouping of several sample points), the arithmetic average concentration of a contaminant at that point or general location, the number of times the contaminant was analyzed, and the number of times the contaminant was detected above the detection limit (media specific) at that point or general location. In calculating arithmetic averages for samples with concentrations below detection limits, a value one-half the detection limit was used for the sample value in the calculation. This method is used for risk assessment purposes because the actual concentration may be between zero and a value just below the reported detection limit. Use of one-half the detection limit attempts to balance underestimating (from using zero as the value) and overestimating (from using the detection limit) of average concentrations. Averages in which one-half the detection limit was used are denoted with a less-than sign in front of the value on the summary table.

Groundwater summaries are composed of data from wells that were grouped together to provide information about a general area or aquifer. Monitoring wells were grouped according to location, hydraulic characteristics, and similar groundwater chemistry. Appendix A Tables 3-2 through 3-5 present the groundwater summaries.

Surface water summaries are provided for each sampling station or group of stations within each sampling phase to provide information for assessing the conditions of the water body at a specific location within a given time period. Appendix A Tables 3-6 through 3-14 present the surface water summaries.

Pond bottom sediment samples are summarized for Zone A within each pond and for all zones regardless of depth, within each pond. These summaries are presented in Appendix A Tables 3-15 and 3-16. Surface samples from exposed tailings (0-2 feet) were taken from Ponds 1, 2, and 3. These are summarized in Appendix A Table 3-17. Sediment samples (0-1 inch) were taken from the Mill-Willow Bypass, in four discrete geomorphic units: the vegetated active channel, unvegetated active channel, vegetated floodplain (first terrace above the active channel), and the unvegetated flood plain. Summaries of these four distinct sampling areas are presented in Appendix A Tables 3-18 and 3-19.

Biological samples (fish and waterfowl) are summarized in Appendix A Tables 3-20 and 3-21.

EXPOSURE ASSESSMENT

Migration and Fate

Contaminant migration mechanisms are depicted in Figure 2-1 of Chapter 2. In addition to those shown, contaminants may be released from the ponds and the Mill-Willow Bypass through:

- High-flow events which cause the resuspension of sediments, further migration downstream, and potentially, dispersion onto the floodplain.

- Major flood events, which could result in the release of large volumes of contaminated sediments that may move downstream to the Clark Fork River and to adjacent floodplains. Sediments, once released from their present anaerobic environment could be oxidized to a more mobile form, resulting in a release of dissolved metals to surface waters or groundwater.

- Dike failure resulting from ground shaking during an earthquake, which could cause berms to slump and sediments to flow like liquid (liquefaction) into downstream areas.

The environmental fate of site inorganic compounds is primarily dependent upon the physical and chemical properties of the system containing the compounds. Precipitation and absorption to sediments are the predominant fate of inorganic compounds in the ponds, although physical aggregation and biological uptake and accumulation also occur at the site.

DRAFT

Current Potential Human Exposure Pathways and Receptors

Data obtained during the remedial investigation indicate a plume of contaminated groundwater is moving north from Pond 1 in the shallow alluvium. Samples obtained in 1985 from the closest drinking water well downgradient of the site (approximately 1 mile downstream) have not detected contaminants above detection limits. Drinking water wells adjacent to the site to the east are approximately 250 feet in bedrock and show no signs of site contaminants. Wells west and south of the site are upgradient of groundwater flow and are not influenced by compounds in the plume. No direct exposures to contaminated groundwater have been identified, therefore no exposure pathways currently exist for contaminants in groundwater.

Because the ponds are a recreational resource in the area, adult contact with surface waters and sediments could occur when hunting or fishing in the Wildlife Management Area. Children are not known to use the ponds for recreation because fishing ponds have been specially built in Warm Springs for their use.[49] Contact with surface water and sediments may also occur on a daily basis for employees of the MDFWP who work in the Wildlife Management Area.

Recreational users and MDFWP employees have the potential to contact exposed tailings at the ponds and along the Bypass, either through direct contact or indirectly through inhalation of wind-entrained tailings. Figure 3-1 shows both exposed tailings areas and residential areas. This figure, including the wind data shown, indicate the potential for residents of the town of Warm Springs to indirectly contact exposed tailings; winds predominantly blow in the direction

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[49] Gallager, 1988.

of the town across exposed tailings areas. The potential also exists, although unlikely due to topographic changes, for residents along the bluff east of the pond system to contact wind-blown exposed tailings.

Human consumption of site waterfowl and fish (keeping fish caught onsite is illegal but could occur) could result in exposure to contaminants accumulated in their tissue. The data indicate concentrations of contaminants detected in edible tissue is similar to that detected in edible tissue from noncontaminated areas. However, exposure to contaminants is additive and this pathway would add to the total amount of contaminants a person could receive from site use.

Potential Future Human Exposure Pathways and Receptors

Should a catastrophic event occur (flood or earthquake) resulting in the failure of pond berms and release of pond materials, contact could occur with surface water and pond bottom sediments. In addition, after the water receded, contaminated sediment spread throughout the floodplain could dry and become airborne, resulting in indirect contact. Downstream residents would be the expected receptors for contact with media that has migrated from the site in this manner.

Additional future exposure pathways, although unlikely, could occur if residential development were to take place within the site (the Pond 1 area). Groundwater in the shallow alluvium could be used as a source of both household and drinking water. Direct contact with sediments and indirect contact with dried sediments or exposed tailings through wind entrainment could occur if a housing development were built in the Pond 1 area. A development of this sort is

unlikely because the population of the area is decreasing.[50] In addition, the site is within the floodway of Silver Bow Creek and flooding could occur annually. On the basis of stability rating, the Corps of Engineers considers the upstream berms to be a high hazard.[51] It is unlikely that a housing development would be built immediately downstream of such high-hazard dikes or in the floodway.

Human Exposure Scenarios and Intake Estimates

Figures 3-2 and 3-3 present, respectively, the three current potential human exposure scenarios and the potential future human exposure scenarios developed for the site. These scenarios were formulated from information on the setting, the nature and extent of contamination, the potential migration of contamination, and the potential exposure pathways. Exposure pathways define the ways potential human receptors (local residents, workers, recreationists) could be exposed to contaminated site media (water, soil, biota, etc.). Exposure scenarios identify the amount of contaminated media consumed, inhaled, or absorbed by quantifying each potential receptor/media/exposure pathway combination for the site.

The quantity of media a receptor can take into his or her body is termed the intake estimate and has the units of milligrams (mg) of media per kilogram (kg) receptor body weight per day (mg/kg/day). Intake estimates are media- and route-specific and are determined according to the type of receptor, the age of the receptor, and the weight of the receptor. Daily intake estimates are the quantity of contaminant taken into the body on a per day basis. Lifetime daily intake estimates take into account:

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50 Manning, 1988.

51 IECO, 1981.

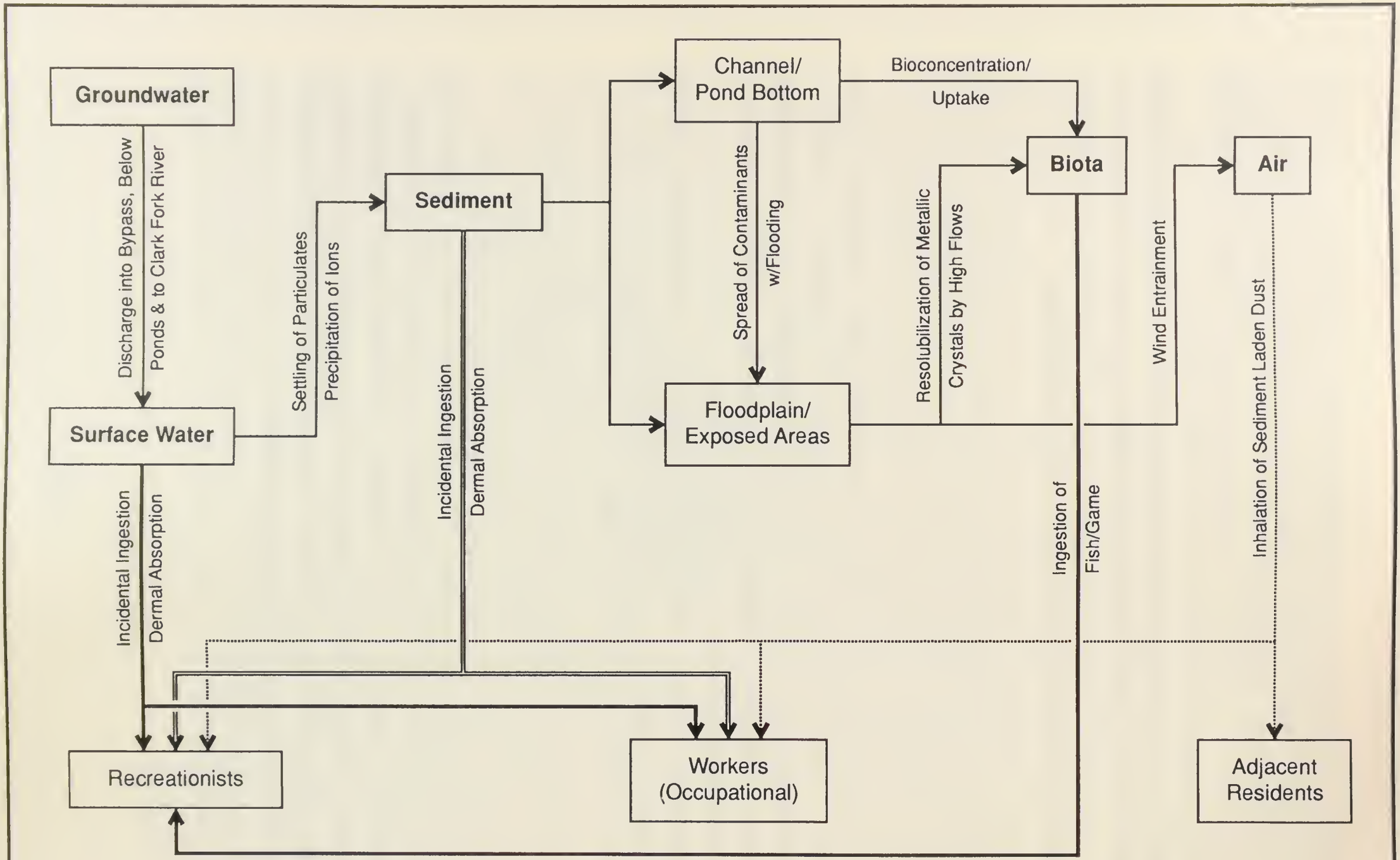

FIGURE 3-2

POTENTIAL CURRENT HUMAN PATHWAYS OF EXPOSURE

WARM SPRINGS PONDS OPERABLE UNIT
FEASIBILITY STUDY

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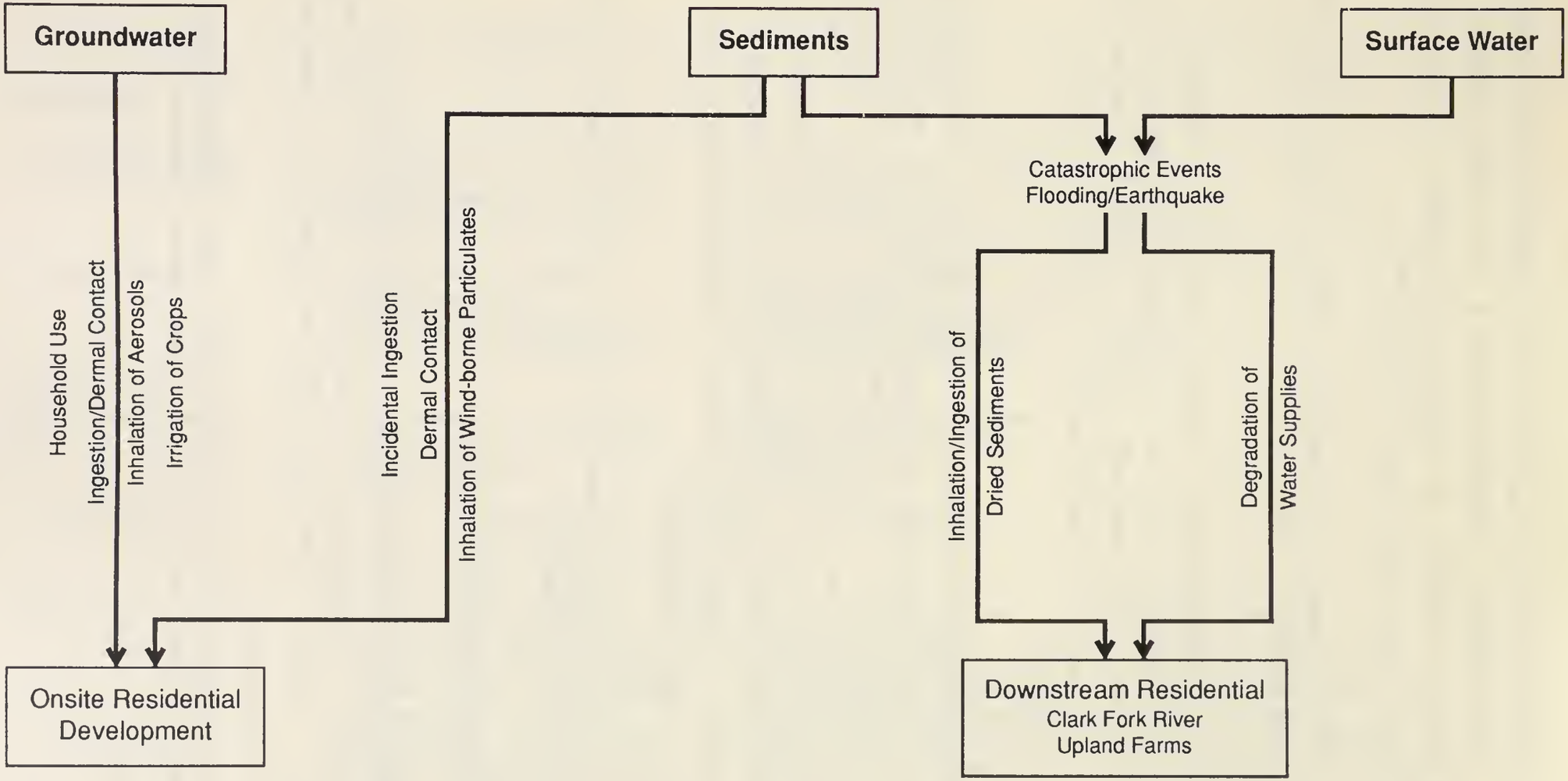

Note: All current exposure pathways would still apply (see Figure 3-2)

FIGURE 3-3

POTENTIAL FUTURE HUMAN PATHWAYS OF EXPOSURE

WARM SPRINGS PONDS OPERABLE UNIT
FEASIBILITY STUDY

BOI24856.N1

- The duration of exposure in a specific age group (for example, children ages 1 to 4 will ingest greater amounts of sediment from hand to mouth contact than adults age 19 and over).

- The frequency of exposure (daily, every other day, once a week, etc.).

- The environmental factors that affect exposure (for example, dust is not generated when soil is frozen, snow covered, or has received greater than 0.01 inch of precipitation over a 24-hour period).[52]

Standardized intake estimates are used whenever possible. For example, the standardized intake of drinking water by an adult is assumed to be 2 liters per day.[53] When standardized intakes are not available, a range of intake values is used to bracket the actual intake. Table 3-1 presents the assumptions and intakes used for each current scenario. It is not possible to quantify intake of media through all pathways nor all scenarios.

Table 3-2 presents the assumptions and intakes used for each potential future scenario.

Exposure Point Concentrations

The exposure point concentration is the concentration of each individual contaminant in a specific media at the point of receptor contact. The full PHEA in Appendix A provides

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[52] United States Environmental Protection Agency (USEPA), 1988c. Superfund Exposure Assessment Manual. EPA 540/1-88/002, Office of Remedial Response, Washington, DC.

[53] USEPA, 1986a.

TABLE 3-1
ASSUMPTIONS AND INTAKES FOR CURRENT HUMAN EXPOSURE SCENARIOS (1)

MEDIA	EXPOSURE SCENARIO: RECREATIONAL	OCCUPATIONAL	RESIDENTIAL
GROUNDWATER	None	None	None
SURFACE WATER			
Incidental Ingestion	o Daily intake of 5 to 25 ml/day o Lifetime daily intake of 0.003 to 0.017 ml/kg/day	o Daily intake of 5 to 25 ml/day o Lifetime daily intake of 0.02 to 0.11 ml/kg/day	None
Dermal Contact	o Daily intake of 0.000014 0.000043 ml/kg/day o Lifetime daily intake of 0.0000007 to 0.000002 ml/kg/day	o Daily intake of 0.000085 to 0.000255 ml/kg/day o Lifetime daily intake of 0.000025 to 0.000075 ml/kg/day	None
SEDIMENT			
Incidental Ingestion	o Daily intake of 10 to 50 mg/day o Lifetime daily intake of 0.007 to 0.03 mg/kg/day	o Daily intake of 10 to 50 mg/day o Lifetime daily intake of 0.04 to 0.21 mg/kg/day	None
Dermal Contact	Not quantified	Not quantified	None
AIR			
Inhalation	o Daily air intake when onsite of 2.4 to 5.2 m3/day o Lifetime daily air intake when onsite of 0.001 to 0.003 m3/kg/day m3/kg/day o Approximately 24.6% of entrainable material is in the respirable range. Dose was adjusted after intake.	o Daily air intake when onsite of 10.4 to 22.4 m3/day o Lifetime daily air intake when onsite of 0.026 to 0.056 m3/kg/day o Approximately 24.6% of entrainable material is in the respirable range. Dose was adjusted after intake.	o Daily air intake of: 5 m3/day for ages 1 to 4 10 m3/day for ages 5 to 11 17 m3/day for ages 12 to 18 20 m3/day for ages 19+ o Lifetime daily air intake of 0.17 m3/kg/day o Approximately 24.6% of entrainable material is in the respirable range. Dose was adjusted after intake.

TABLE 3-1, Continued.

MEDIA/ROUTE	EXPOSURE SCENARIO: RECREATIONAL	OCCUPATIONAL	RESIDENTIAL
AIR			
Ingestion	o 75% of the material inhaled (but not respired) was assumed to be ingested. May overestimate the actual quantity ingested due to inhalation as % exhaled was not factored in.	o 75% of the material inhaled (but not respired) was assumed to be ingested. May overestimate the actual quantity ingested due to inhalation as % exhaled was not factored in.	o 75% of the material inhaled (but not respired) was assumed to be ingested. May overestimate the actual quantity ingested due to inhalation as % exhaled was not factored in.
BIOTA			
Ingestion of Fish	o Daily intake of 26 to 43 g/day o Lifetime daily intake of 0.16 to 0.26 g/kg/day	None	None
Ingestion of Waterfowl	o Daily intake of 21 to 27 g/day o Lifetime daily intake of 0.13 to 0.17 g/kg/day	None	None
FURTHER ASSUMPTIONS	o Adult exposures only; 70 kg weight o 41 days spent onsite each year for 30 yrs/70 yr life. Dust exposures limited to 32 days/yr due to snow. o Surface area for dermal contact of 1700 cm2 for 5 to 15 min/day. o Inhalation rate of 0.6-1.3 m3/hr for 4 hrs onsite. o 14 fish/season kept; 3-5 lbs each; 50% edible. 39 birds shot/season; each weights 1000 g, 20-25% edible.	o Adult exposures only, 70 kg weight o 250 work days are spent onsite each yr over a 30 yr worklife/70 life. Dust exposures limited to 150 days/yr due to snow cover. o Surface area for dermal contact of 1700 cm2 for 30 to 75 min/day. o Inhalation rate of 1.3-2.8 m3/hr for 8 hrs onsite.	o Exposures occur 24-hrs/day, 215 days/year (period w/o snow cover) over a 70 yr life. o Four age categories considered: child 1 to 4 yrs weighing 14 kg; older child ages 5 to 11 yrs weighing 29 kg; adolescent 12 to 18 yrs weighing 57 kg; adult 19 yrs and older weighing 70 kg.

(1). For specific details and calculations see Appendix A Table 4-3 through 4-5.

TABLE 3-2
ASSUMPTIONS AND INTAKES FOR POTENTIAL FUTURE HUMAN EXPOSURE SCENARIOS (1)

MEDIA	EXPOSURE SCENARIO: ONSITE RESIDENTIAL	EXPOSURE SCENARIO: DOWNSTREAM CATASTROPHIC EVENT
GROUNDWATER		
Ingestion	o Daily ingestion of: 1 l/day for ages 1 to 4 years 1 l/day for ages 5 to 11 years 2 l/day for ages 12 to 18 years 2 l/day for ages 19+ years o Lifetime daily ingestion of 0.03 l/kg/day	Not quantified
Dermal Contact	Not quantified	Not quantified
Inhalation of aerosols	Not quantified	Not quantified
SURFACE WATER	None (2)	Not quantified
SEDIMENT		
Incidental Ingestion	o Daily ingestion through contact of: 100 to 590 mg/day for ages 1 to 4 years 50 to 330 mg/day for ages 5 to 11 years 50 to 140 mg/day for ages 12 to 18 years 50 to 100 mg/day for ages 19+ years o Lifetime daily ingestion of 0.7 to 2.86 mg/kg/day	
Dermal Contact	Not quantified	Not quantified
AIR		
Inhalation	o Daily air intake of: 5 m3/day for ages 1 to 4 years 10 m3/day for ages 5 to 11 years 17 m3/day for ages 12 to 18 years 20 m3/day for ages 19+ years	Not quantified

TABLE 3-2, Continued.

MEDIA	EXPOSURE SCENARIO: ONSITE RESIDENTIAL	EXPOSURE SCENARIO: DOWNSTREAM CATASTROPHIC EVENT
AIR		
Inhalation, cont.	o Lifetime daily air intake of 0.17 m3/kg/day o 24.6% of entrainable material is in the respirable range.	
Ingestion	o The 75% of material inhaled but not respired is ingested.	Not quantified
BIOTA	None (3)	Not quantified
FURTHER ASSUMPTIONS	o Exposures occur 24-hours per day, 365 days per year for a 70 year lifetime. o Inhalation exposures limited to 215 days per year because of snow cover. Four age/weight/intake categories considered: child 1 to 4 years weighing 14 kg older child 5 to 11 years weighing 29 kg adolescent 12 to 18 years weighing 57 kg adult 19 years and older weighing 70 kg.	

(1). For specific details and calculations see Appendix A Table 4-6.
(2). Surface water is assumed to be gone from the Pond 1 area.
(3). This pathway was not considered in this scenario. See current recreational for an estimate on biota ingestion.

exposure point concentrations used in the estimation of risk. Exposure point concentrations were taken from actual site data at specific locations where receptors could contact the media. Concentrations of contaminants in air are the exception to this; dust emissions and resulting contaminant concentrations were modeled using the Industrial Source Complex (ISC) model.[54,55] Refer to Appendix A for a full description of the air model. Table 3-3 identifies the Appendix A data tables that were used for obtaining exposure point concentrations.

Potential Environmental Exposure Pathways and Receptors

Potential environmental exposure pathways are shown in Figure 3-3. Media where exposure could occur and routes that could result in contaminated media intake can vary between species according to dietary demands, habitat, foraging behavior, and other species characteristics. For example, diving ducks (redheads) feed primarily on small aquatic animals, whereas puddle ducks (mallards) are primarily plant eaters. Within species, media intake can vary according to life-stage or sex. For example, the diet of adult female mallards changes to insects during egglaying and nesting.

Environmental receptors to contaminants detected in media onsite include terrestrial and aquatic plants and animals that utilize the site for foraging, habitat, or both. Downstream receptors are primarily aquatic life (fish,

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54 United States Environmental Protection Agency (USEPA), 1985. Compilation of Air Pollution Emission Factors, Vol. 1, Section 11.2.3, A-24. Office of Air Quality Planning and Standards, Research Triangle Park, North Carolina.

55 United States Environmental Protection Agency (USEPA), 1988d. Unimap, Version 6. Office of Air Quality Planning and Standards, Research Triangle Park, North Carolina.

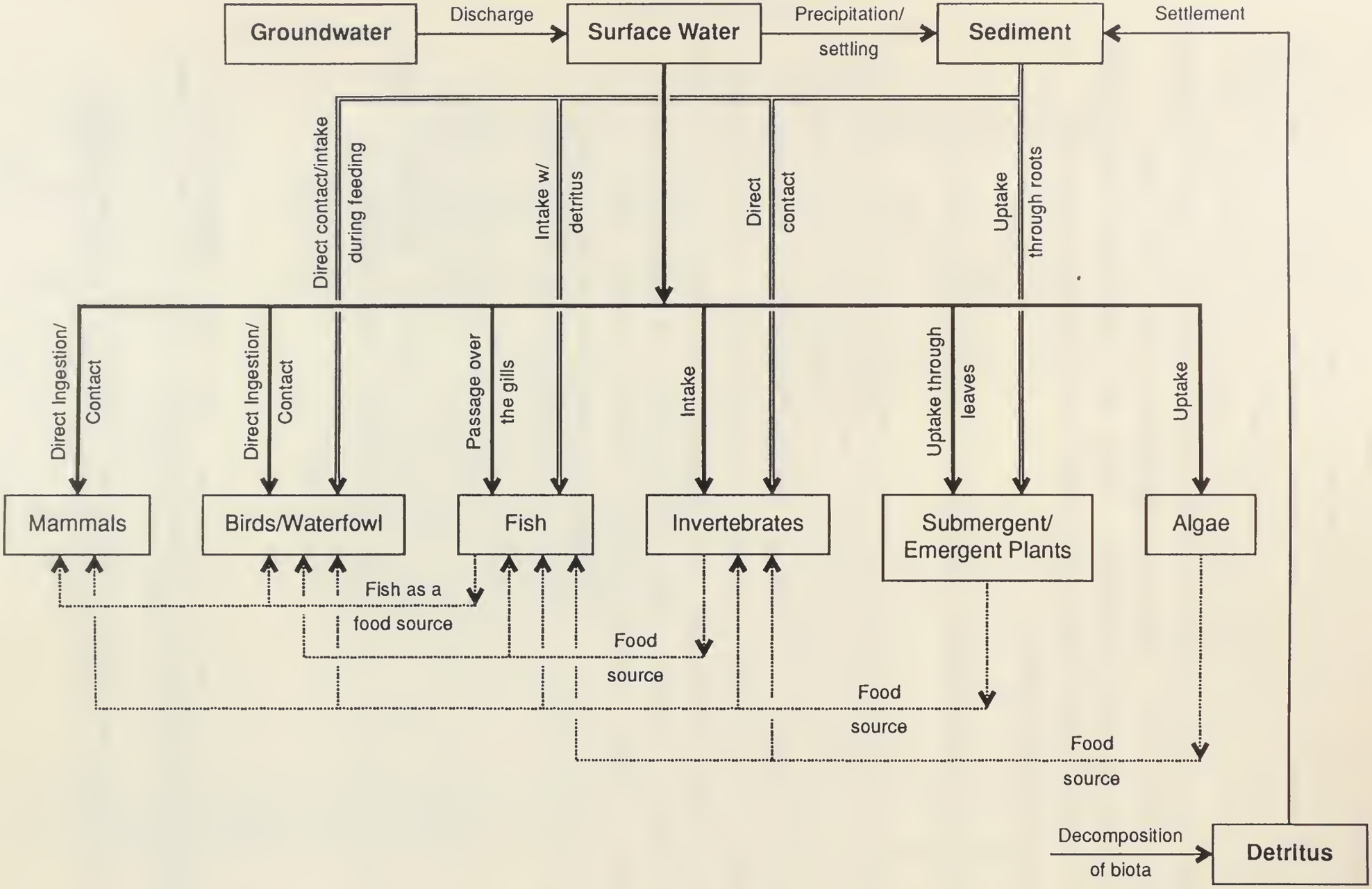

FIGURE 3-4

POTENTIAL ENVIRONMENTAL EXPOSURE PATHWAYS AND RECEPTORS

WARM SPRINGS PONDS OPERABLE UNIT
FEASIBILITY STUDY

BOI24856.N1

TABLE 3-3
REFERENCE TO EXPOSURE POINT CONCENTRATIONS BY EXPOSURE SCENARIO

MEDIA	EXPOSURE SCENARIO			
	RECREATIONAL	OCCUPATIONAL	CURRENT RESIDENTIAL	FUTURE ONSITE RESIDENTIAL
GROUNDWATER Ingestion	None	None	None	o Pond 1 data, Appendix A Table 3-4.
SURFACE WATER Incidental Ingestion	o Wildlife Ponds and Pond 2 Appendix Tables 3-8 and 3-9.	o Pond Inflow/Opportunity discharge/Wildlife Ponds/ Pond outflow, Appendix A Tables 3-6, 3-8, 3-10, and 3-14.	None	None
Dermal Contact	o As above, dissolved concentrations only.	o As above, dissolved concentrations only.	None	None
SEDIMENT Incidental Ingestion	o Pond 2 exposed areas, Appendix A Table 3-17.	o Pond 2 exposed areas, Appendix A Table 3-17.	None	o Pond 1 exposed areas, Appendix A Table 3-17.
AIR Inhalation	o Modeled concentration at Wildlife Ponds, Appendix A Table 4-8	o Modeled concentration at Wildlife Ponds, Appendix A Table 4-8	o Modeled concentration at Warm Springs and east side residences, using source apportioned contribution from the pond system, see Appendix A Table 4-8. Also AMC data for Warm Springs.	o Modeled concentration at Pond 1 residence using source apportioned, contribution, Appendix A Table 4-8.
Ingestion	o As above.	o As above.	o As above.	o As above.

TABLE 3-3, Continued.

MEDIA	EXPOSURE SCENARIO			
	RECREATIONAL	OCCUPATIONAL	CURRENT RESIDENTIAL	FUTURE ONSITE RESIDENTIAL
BIOTA				
Ingestion of Fish	o Muscle tissue only, Appendix A Table 3-19	None	None	None
Ingestion of Waterfowl	o Adult birds only, Appendix A Table 3-20	None	None	None

invertebrates, and algae) in the Clark Fork River because of downstream movement of sediments, surface water, and resolubilized metal salts from the Mill-Willow Bypass.

RISK ASSESSMENT

Human Risk Characterization

Before the effects of exposure to a contaminant can be estimated, it must be decided if the constituent end-point of toxicity is carcinogenic or noncarcinogenic through a specific route of exposure (ingestion, inhalation, or dermal contact). Compounds that produce a known, potential, or possible carcinogenic response in humans are typically given a cancer potency value specific to the route of exposure. Most potency values are derived by using the upper 95 percent confidence limit on the slope of the dose-response curve obtained from a linearized multistage model of animal data. Potency factors are also derived from dose response data from human epidemiologic studies fitted to dose-time-response curves. Potency factors use conservative assumptions and are unlikely to underestimate true risk. Potency factors used in this assessment are listed on Table 3-4.

To quantify carcinogenic risk, the cancer potency value, specific to the route of exposure, is multiplied by the lifetime daily intake and the exposure point concentration. The product is the potential excess lifetime cancer risk, which is the probability of getting cancer compared to the risk

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TABLE 3-4
PUBLISHED TOXICITY VALUES

PARAMETER	TOXICITY VALUES FOR NONCARCINOGENIC EFFECTS				TOXICITY VALUES FOR CARCINOGENIC EFFECTS (1,2)			
	Oral Route		Inhalation Route		Oral Route		Inhalation Route	
	AIC (1) (mg/kg/day)	RfD (2) (mg/kg/day)	AIC (1) (mg/kg/day)	RfD (2) (mg/kg/day)	Potency Factor (mg/kg/day)-1	W/E (3)	Potency Factor (mg/kg/day)-1	W/E (3)
Aluminum								
Antimony		4.0E-04						
Arsenic					1.5 (4)	A	50	A
Barium		5.0E-02		1.0E-04				
Beryllium		5.0E-03					8.4	B2
Cadmium		5.0E-04					6.1	B1
Chromium (total)		1.0E+00	5.0E-03					
Chromium (IV)							41.0	A
Copper	3.7E-02		1.0E-02					
Iron			8.6E-03					
Lead	1.4E-03 (5)		4.3E-04			B2 (2)		B2 (2)
Magnesium								
Manganese		2.0E-01		3.0E-04				
Mercury	2.0E-03		5.1E-05					
Nickel		2.0E-02 (6)					0.84 (6)	A
Selenium	3.0E-03		1.0E-03					
Silver								
Vanadium	2.0E-02							
Zinc	2.1E-01		1.0E-02					

(1). Source: EPA, 1986c.
(2). Source: EPA, 1989e; EPA, 1989a.
(3). W/E = Weight of Evidence rating; see text for a definition.
(4). Source: Thomas, 1988.
(5). This value has been withdrawn by EPA.
(6). This value is specific to nickel refinery dust.
NOTE: Scientific notation used for ease in reading small values. For example, the notation 3.0E-04 is the value 0.0003.

with no exposure.[56] Cancer risk estimates are rounded to the nearest significant digit. For example, the risk 1×10^{-6} represents the probability that one person in one million persons exposed to a carcinogen over a lifetime (70 years), will develop cancer (ignoring background cancer cases).

Toxicity values for compounds that exhibit noncarcinogenic effects through a specific exposure route are termed reference doses (RfD) or acceptable intake for chronic exposure (AIC). The noncarcinogenic toxicity values used in this assessment are presented on Table 3-4. The RfD for a compound is peer reviewed and is considered to be the level unlikely to cause significant adverse effects, based on a threshold mechanism. The RfD (or AIC) can be used as a comparison against a dose obtained through exposure. Adverse health effects could potentially result from exposure to compounds which produce noncarcinogenic effects if the dose received is higher than the RfD (or AIC).[57]

Risks are presented in Table 3-5 by exposure scenarios for each pathway that could be quantified. Risks from exposure to multiple media, within a scenario, are also included in Table 3-5. Risk could be additive across exposure scenarios. For example, a downwind resident could utilize the ponds for recreational purposes and be exposed to contaminants while at the ponds in addition to inhaling contaminated dust that has moved offsite. Persons living in the towns of Anaconda or Butte could use the ponds for recreational purposes, adding to their total excess lifetime risk from exposure to similar contaminants at their residences and work places.

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56 USEPA, 1986a.

57 Ibid.

TABLE 3-5
RISK SUMMARY FOR CURRENT HUMAN EXPOSURE SCENARIOS (1)

MEDIA	EXPOSURE SCENARIO: RECREATIONAL	OCCUPATIONAL	RESIDENTIAL
GROUNDWATER	None	None	None
SURFACE WATER			
Incidental Ingestion	Maximum excess lifetime cancer risk of 6 x 10-7 and average risk (2) of 5 x 10-8. No risk identified from exposure to non-carcinogenic compounds.	Maximum excess lifetime cancer risk of 2 x 10-5 and average risk of 2 x 10-7. Highest contribution from pond outflow. No risk identified from exposure to non-carcinogenic compounds.	None
Dermal Contact	No data with which to evaluate carcinogenic risk. (3) No risk from exposure to dissolved concentration of non-carcinogenic compounds was identified. Hazard index = 0.00000009 (9E-08). (4)	Data available to evaluate cancer risk during high flow events only. Maximum excess lifetime cancer risk of 4 x 10-9 from arsenic. No risk from exposure to dissolved concentration of non-carcinogenic compounds was identified. Hazard index = 0.00058 (5.8E-04).	No data with which to evaluate downstream residential contact.
SEDIMENT			
Incidental Ingestion	Maximum excess lifetime cancer risk of 4 x 10-5 and average risk of 3 x 10-6. Most probable CDI or maximum plausible CDI of non-carcinogenic compounds did not indicate a risk.	Maximum excess lifetime cancer risk of 2 x 10-4 and average risk of 2 x 10-5. Maximum plausible CDI and most probable CDI of non-carcinogenic compounds did not indicate a risk.	None
Dermal Contact	Not quantified. Anticipated that additional risk from this pathway would be minimal, see dermal contact with surface water.	Not quantified. Anticipated that additional risk from this pathway would be minimal, see dermal contact with surface water.	None

TABLE 3-5, CONTINUED.

MEDIA/ROUTE	EXPOSURE SCENARIO		
	RECREATIONAL	OCCUPATIONAL	RESIDENTIAL
AIR			
Inhalation	Maximum excess lifetime cancer risk of 1 x 10-7 and average risk of 5 x 10-8 driven by arsenic and cadmium. Maximum plausible and most probable CDIs did not exceed acceptable intake values.	o Maximum excess lifetime cancer risk of 2 x 10-6 and average risk of 9 x 10-7 driven by arsenic and cadmium. Maximum plausible amd most probable CDIs did not exceed acceptable intake values.	o At the town of Warm Springs, modeled dust emissions from the pond system result in an excess lifetime cancer risk of 6 x 10-6. No risk was identified from exposure to noncarcinogenic compounds for any age group. o At the town of Warm Springs, AMC PM10 data on air contaminants (1983 data) results in an excess lifetime cancer risk of 10-6. o At residences east of the ponds, excess lifetime cancer risk ranges from 0 to 7 x 10-6. Wind direction/duration were roughly included in the conversion of modeled dust concentration from 1-hr maximums to 24 hr values and annual values. However, results may overestimate actual risks due to topographic changes and its effect of dust dispersion. o No risk was identified from exposure to non-carcinogenic compounds for any age group.
Ingestion	Ingestion as a result of inhalation of wind-blown sediment may lead to an excess lifetime cancer risk of 2 x 10-8 for maximum inhalation rates and 7 x 10-9 for most probable inhalation rates. No risk was identified from exposure to non-carcinogenic compounds.	o Ingestion as a result of inhalation of wind-blown sediment may lead to an excess lifetime cancer risk of 4 x 10-7 for maximum inhalation rates and 2 x 10-7 for most probable inhalation rates. No risk was identified from exposure to non-carcinogenic compounds.	o At the town of Warm Springs, modeled emissions results in an excess life time cancer risk of 1 x 10-6 through ingestion from inhalation. Using AMC air data the resulting risk is 2 x 10-6. No risk was identified from exposure to non-carcinogenic compounds for any age group.

TABLE 3-5, CONTINUED.

MEDIA/ROUTE	EXPOSURE SCENARIO: RECREATIONAL	OCCUPATIONAL	RESIDENTIAL
AIR Ingestion			o For those residences east of the ponds, the excess lifetime cancer risk range is 1 x 10-6 to 8 x 10-7. No risk was identified from exposure to non-carcinogenic compounds for any age group.
BIOTA Ingestion of Fish/ Waterfowl	Maximum excess lifetime cancer risk from ingestion of fish using assumptions of scenario of 6 x 10-5. This could be as low as 0 as keeping fish is illegal. Maximum risk from ingestion of waterfowl of 1 x 10-5. No risk identified from exposure to non-carcinogenic compounds through ingestion of tissue.	None	None
TOTAL MULTIMEDIA RISK	1 x 10-4 excess lifetime cancer risk associated with assumed maximum plausible chronic daily intake (CDI)(5) Potential threat from non-carcinogenic compounds was not identified.	2 x 10-4 excess lifetime cancer risk associated with assumed maximum plausible chronic daily intake (CDI) driven by ingestion.	Multimedia exposures not considered for this scenario. Exposures could include those from either recreational use of the area or from working at the ponds or both.

(1). See Appendix A for a complete discussion of potential risk.
(2). The terms 'maximum' and 'average' in relation to risk are modifiers meant to indicate the use of maximum and average intakes and concentrations and is not meant to imply that risk is anything other than upper bound estimates.
(3). No dissolved concentrations of constituents assumed to be carcinogenic through dermal exposure. Compounds exhibiting carcinogenicity through dermal exposure assumed to be those that are carcinogenic through ingestion.
(4). Hazard index is a method of determining potential health risk from total exposure to non-carcinogenic compound through a single exposure route and media.
(5). CDI is a term that combines the assumed intake rate and the concentration of the contaminant in a specific media.

These cumulative risks have not been quantified in this assessment.

Pathways and contaminants not specifically quantified in this assessment would add to the total carcinogenic and non-carcinogenic risk. Table 3-5 also includes a subjective evaluation of the risk from unquantifiable pathways.

Risks from potential future scenarios are presented in Table 3-6.

Environmental Risk Characterization

Monthly average concentrations of inorganic compounds in site surface water exceed acute standards for the protection of aquatic life. Stress on aquatic life could manifest itself as reduced growth, reduced fertility, increased mortality, and/or morbidity, etc. Reports from MDFWP do not indicate obvious chronic stress in the aquatic ecosystem; fish are large, invertebrates are present, and the environment in the ponds appears to be stable.[58] However, Montana chronic freshwater aquatic standards for copper, cadmium, lead, and zinc are regularly exceeded throughout the pond system.

One of the principal adverse environmental impacts associated with contaminants at the site is the offsite migration of metal salts from the Mill-Willow Bypass during rainfall events. Fishkills in the Clark Fork River have occurred following summer thunderstorm events and are believed to result from solubilization of metallic salts in the

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[58] Hadley, William, 1988. Montana Department of Fish, Wildlife and Parks, Deer Lodge Fish Biologist/Area Maanger, Deer Lodge, Montana. Personal communication.

TABLE 3-6
RISK SUMMARY FOR POTENTIAL FUTURE HUMAN EXPOSURE SCENARIOS (1)

MEDIA	EXPOSURE SCENARIO: ONSITE RESIDENTIAL	EXPOSURE SCENARIO: DOWNSTREAM CATASTROPHIC EVENT
GROUNDWATER		
Ingestion	Maximum or average (2) excess lifetime cancer risk of 1 x 10-3. Intake of manganese by all age groupsexceed acceptable intakes.	Not quantified. Release of large volume of contaminated surface water and sediments could adversely impact downstream groundwater resources but it is not possible to determine the degree to which this would occur.
Dermal Contact	Not quantified. Could add to the total intake of constituents in groundwater, but it is not anticipated to contribute significantly.	
Inhalation of aerosols	Not quantified. Could add to the total intake of constituents in groundwater, but the magnitude is not known.	
SURFACE WATER	None	Not quantified. Aside from the physical damage from a release of a large volume of water, the release of contaminants in sediment back into the water column could adversely affect surface water and activities involving surface water, for example, recreational contact.
SEDIMENT		
Incidental Ingestion	Maximum excess lifetime cancer risk of 2 x 10-3 and average risk of 3 x 10-4. The daily intake cadmium, manganese, copper, and zinc, based on the maximum concentration, exceeded the acceptable intakes for the child and adolescent age groups. For older children, only the maximum	Spread of large volumes of contaminated sediment into downstream area could result in the ingestion of sediment by downstream receptors but the magnitude of the risk is not known.

TABLE 3-6, CONTINUED.

MEDIA	EXPOSURE SCENARIO: ONSITE RESIDENTIAL	EXPOSURE SCENARIO: DOWNSTREAM CATASTROPHIC EVENT
SEDIMENTS, continued		
Incidental ingestion, continued	concentration of manganese exceeded the acceptable intake. For all three groups, the acceptable intakes were not exceeded by the daily intakes based on the average concentrations.	
Dermal Contact	Not quantified. Could add to the total intake of constituents from sediments, but it is not anticipated to contribute significantly.	Not quantified. Could add to the total intake of constituents from sediments, but it is not anticipated to contribute significantly.
AIR		
Inhalation	Potential excess lifetime cancer risk of 8 x 10-6.	Not quantified. This could be a major pathway after waters receed and sediments dry out.
Ingestion	The potential excess lifetime cancer risk is estimated as 1 x 10-6.	Not quantified. This could be a major pathway after waters receed and sediments dry out.
TOTAL MULTIMEDIA RISK	3 X 10-3 excess lifetime cancer risk associated with assumptions of scenario and maximum plausible intakes. Potential threat from non-carcinogenic compounds through ingestion of cadmium, and inhalation of lead iron, copper and zinc.	Primary risk would be through inhalation/ ingestion of dried sediments that had been dispersed throughout the floodplain. Other risks could include contamination of groundwater and surface water supplies.

(1). For specific details of risk, see Appendix A. Not all pathways have been quantified.

(2). The terms 'maximum' and 'average' in rleation to risk are modifiers meant to indicate the use of maximum and average intakes and concentrations and is not meant to imply that risk is anything other than upper bound estimates.

bypass.[59] See Chapter 4 for a more detailed discussion of the probable causes of the fishkills.

Potential future impacts to the aquatic ecosystem of the ponds, the bypass, and the Clark Fork River would occur if a catastrophic event caused a breach in the berms of the pond system, possible liquefaction of pond sediments, and rapid downstream movement of sediment and surface water. Increased suspended particulates in the water column would be detrimental to fish and other aquatic life, scouring would eliminate habitat, and the release of sediment contaminants could result in major surface water quality impacts for miles downstream. Riparian plants and rooted emergent plants could be eliminated by scouring as could wetlands adjacent to the river.

Significant areas of the site are completely barren of vegetation (approximately 60 acres of exposed tailings along the Mill-Willow Bypass, above Pond 3, and below Pond 1). Of areas sampled in the bypass, the unvegetated floodplain exhibited the highest concentrations of most metals measured.

Potential future impacts to the terrestrial ecosystem of the site could result from catastrophic events, as described above for the aquatic ecosystem. Habitat would be eliminated, food and water sources affected, and the ecosystem generally would be severely impacted.

Chronic impacts to wildlife are very difficult to detect. Chronic intake and accumulation of contaminants may result in impairment of health, which could be indicated by increased susceptability to predation or disturbances of repro-

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[59] Montana Department of Fish, Wildlife, and Parks (MDFWP), 1988. Clark Fork Basin Project Status Report and Action Plan. H.E. Johnson, coordinator.

ductive cycles. These chronic effects may or may not be detected in species currently using the ponds. Current impacts to wildlife at the site are unknown. Potential future impacts to wildlife both at the site and downstream of the site could be severe if a catastrophic event were to occur.

UNCERTAINTIES AND LIMITATIONS

A risk assessment involves the use of both scientifically verifiable data and a variety of subjective assumptions. The accuracy of the assessment is influenced by the degree of uncertainty in site data, the toxicological data from which a compound's toxic effects are estimated, and the assumptions used to estimate dose. These limitations must be kept in mind when evaluating the risk estimates resulting from the assumptions and scenarios used in this assessment.

RISK-BASED CLEANUP GOALS DEVELOPMENT

Contaminant-specific ARARs have been identified for three of the operable unit's contaminated media. However, contaminant-specific ARARs do not exist for soils and sediments. The State of Montana has determined that the Warm Springs Ponds Operable Unit should be cleaned up so that concentrations of constituents in soils are reduced to levels associated with an excess lifetime carcinogenic risk between 10^{-4} to 10^{-7}.

Using assumptions stated in the PHEA, potential human health risks (greater than 10^{-7} excess lifetime cancer risk for carcinogens or equal to the "acceptable intake" for noncarcinogens) were identified for:

- Ingestion of sediments (tailings) for all exposure scenarios

- Inhalation of sediment-laden dust for all exposure scenarios

- Incidental ingestion of surface water through occupational contact

- Ingestion of groundwater as a drinking water source for the potential future residential scenario

Tables 6-26 and 6-27 in the PHEA (Appendix A) summarize the highest excess lifetime cancer risks identified for the site and the exceedances of constituents with noncarcinogenic effects by exposure scenario and exposure route.

CLEANUP GOAL CALCULATION METHODOLOGY

Carcinogenic Effects

A cleanup concentration has been calculated for each scenario and exposure route that resulted in an estimated excess lifetime cancer risk greater than 1×10^{-7} using the assumptions outlined for the exposure scenario in the PHEA. If a combination of constituent produced a risk that triggers calculation of a cleanup concentration (a risk of 1×10^{-7} or greater), but each individual constituent alone would not, the proportion that each constituent contributes to the total estimated risk was determined (as a percentage) and applied to the target risk of 1×10^{-7} from which a soil cleanup concentration for that constituent was calculated. Soil cleanup concentrations were determined by examining

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each scenario that identified a risk greater than 10^{-7} and altering the soil concentration until the target risk of 1.00×10^{-6} (or a combination of risk that sums to 1×10^{-7} from multiple constituents) was generated. Based on this analysis, a soil cleanup concentration of 250 ppm has been selected for arsenic.

Noncarcinogenic Effects

The concentration of a constituent in soils or sediments necessary to make the chronic daily intake (CDI) of that constituent equal to its "acceptable intake" is calculated for each constituent that produces noncarcinogenic effects that exceeds its "acceptable intake" under the assumptions of a scenario. The term "acceptable intake" is defined as either the reference dose (RfD) if one is available, or the acceptable intake chronic (AIC). The RfD and AIC are route specific; values are available for inhalation and ingestion only.

Lead

Target cleanup goals cannot be derived from calculations based on an RfD or AIC because such numbers have not been established for lead.

The USEPA has used a target cleanup range of 500 to 1,000 ppm for lead at other Superfund sites.[60] For the Warm Springs Ponds Operable Unit, the target cleanup level for lead, as for all the other contaminants, will be determined by the USEPA and the State of Montana and stated in the Record of Decision. A target cleanup level of 750 ppm has been preliminary selected for lead.

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60 USEPA, 1989. OSWER Directive Interim Guidance on Establishing Soil Lead Cleanu Levels at Superfund Sites.

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POTENTIAL CLEANUP GOALS FOR THE OPERABLE UNIT

The following discussion addresses potential cleanup goals for exposure scenarios to soil and sediment where excess lifetime human health risks are 10^{-7} or greater for constituents that exhibit carcinogenic effects, or where constituents with noncarcinogenic effects exceed their "acceptable intake."

Current Recreational Scenario

Incidental Ingestion. The PHEA evaluated the incidental ingestion of sediments from the pond area by adults that use the ponds for recreational purposes. Total intake of sediments was partitioned according to various areas where incidental ingestion could occur from hand-to-mouth activity. Contributions to the total cancer risk from Pond 2 (2×10^{-5}) and exposed sediments (2×10^{-5}) are roughly equal and largely determine the total risk. The contribution from the Wildlife Ponds (1×10^{-6}) does not influence the total cancer risk. Therefore, the target excess cancer risk for each of the two areas responsible for the total excess cancer was set at 5×10^{-8} in order to obtain a total target excess cancer risk from this exposure route of 1×10^{-7}. Table 3-1 presents the concentrations of arsenic in soil that result in an excess lifetime cancer risk of 1×10^{-7} through incidental ingestion using the assumptions of the recreational scenario.

Current Occupational Scenario

Assumptions used in the current occupational scenario result in excess lifetime cancer risks greater than the target cancer risk of 1×10^{-7} for incidental ingestion of sediments and inhalation of sediment-laden dust that originated from exposed areas on the ponds.

Table 3-7
SUMMARY OF POTENTIAL "CLEANUP" GOALS
(MOST PROBABLE INTAKES THROUGH ALL EXPOSURE SCENARIOS)

Scenario	Average Soil Concentration to Achieve a Target Cancer Risk Level of: (mg/kg)								Soil Concentration to Achieve the CDI = AIC[a] (maximum plausible intake rates)		
	1×10^{-7}		1×10^{-6}		1×10^{-5}		1×10^{-4}				
	Cd	As	Cd	As	Cd	As	Cd	As	Mn	Cu	Zn
Current Recreational											
Ingestion											
Pond 2 Bottom Sediments		19		190							
Pond 2 Exposed Sediments		9.5		95							
Current Occupational											
Ingestion											
Pond 2 Exposed Sediments		1.7*[b]		17		170		1,700			
Inhalation											
All Exposed Sediments	5,600[c]	254[c]									
Current Downwind Residential											
Inhalation (all source areas)											
Warm Springs	88[c]	38[c]	880[d]	380[d]							
Eastside Residences	88[c]	38[c]	880[f]	380[f]							
Ingestion Through Inhalation											
Warm Springs		228*									
Eastside Residences		228*									
Potential Future Onsite Residential											
Ingestion											
Pond 1 Exposed Sediments		0.1*		1*		10		100	4,800[ef]	900[e]	5,000[e]
Inhalation											
All Sources Areas w/in the Ponds	88[c]	38[c]									

[a] Daily Intake = Acceptable Intake Chronic (mg/kg in soil)
[b] An asterisk (*) by the value indicates it is less than concentrations in other areas of the state (see Table 7 of the Technical Memorandum "Risk Based Potential Soil, Cleanup Levels").
[c] These two must be added together to obtain a 10^{-7} cancer risk.
[d] These two must be added together to obtain a 10^{-6} cancer risk.
[e] "Cleanup" concentration for a child (1 to 4 years old).
[f] Manganese "cleanup" concentration for an older child (5 to 11 years old) is 35,000 mg/l.

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Incidental Ingestion. The PHEA evaluated the incidental ingestion of sediments from exposed areas for individuals working at the ponds. Arsenic was the only constituent detected at the site that produces carcinogenic effects through ingestion. Only the sediments from exposed areas were considered in this scenario. Table 3-7 summarizes the potential soil cleanup concentrations.

Inhalation. Inhalation of sediment-laden dust while working at the ponds resulted in an estimated excess lifetime cancer risk of 2×10^{-6}, primarily determined by cadmium (30 percent) and arsenic (50 percent). Chromium contributed 20 percent to the total excess lifetime cancer risk if all chromium present is assumed to be hexavalent. A target cancer risk of 1×10^{-7} was based on inhalation of cadmium and arsenic, ignoring the contribution of chromium (20 percent) to the total. Chromium was not considered as it is unlikely that the chromium present in soils and sediments is hexavalent chrome (the carcinogenic specific). Hexavalent chrome is rapidly reduced to trivalent chrome in soils. The soil source concentration of cadmium and arsenic that would result in a dust concentrations that would produce the total target cancer risk of 1×10^{-7} is reported on Table 3-7.

The toxicity values derived for inhalation of metals are based on exposure to vapors or fumes, not to dust (although only dust occurs at the site). In an effort to be conservative, these toxicity values are assumed to be applicable to dusts. Risks were calculated from ingestion of dusts through the inhalation pathway. Cleanup concentrations were not calculated through this pathway as cleanup concentrations calculated for direct ingestion will mitigate the potential risk. (Risks were higher for direct ingestion by three orders of magnitude.)

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Current Residential Scenario

The current residential scenario only considered the inhalation and subsequent ingestion of sediment-laden dusts that could blow from the site. Winds blow to the north/northwest (out of the south/southeast) over 40 percent of the time. The predominant downwind receptors are the residents of the town of Warm Springs. However, to be conservative, the residences east of the ponds up on the cliffs were considered "downwind receptors" as well.

The upper-bound excess lifetime cancer risk from cadmium and arsenic through inhalation of wind-blown sediments for Warm Springs residents was estimated using modeled concentrations to be 6×10^{-6}. The excess lifetime cancer risk for residents east of the ponds, through inhalation of wind-blown sediments originating from the exposed areas of the ponds, was estimated to be as high as 7×10^{-6} (also driven equally by arsenic and cadmium). The soil concentrations of arsenic and cadmium that would result in a 10^{-7} cancer risk from inhalation of dusts through the current residential scenario are reported in Table 3-7.

Potential Future Onsite Residential Scenario

Ingestion. Arsenic was the only constituent detected at the site that produces carcinogenic effects through ingestion Ingestion of maximum reported concentrations of manganese, copper, and zinc in soils at the maximum plausible intake rates resulted in an exceedance of "acceptable intakes" for young children (1 to 4 years of age). Ingestion of the maximum concentration of manganese at maximum plausible intakes by older children (5 to 11 years) resulted

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in an exceedance of the RfD. Potential cleanup concentrations for these compounds are reported in Table 3-7.

Inhalation. Inhalation of dusts arising from soils throughout the pond system resulted in an estimated 8×10^{-6} excess lifetime cancer risk for residents of a potential future housing development on Pond 1. The risk was driven primarily by arsenic, cadmium, and chromium.

Risk was apportioned equally to arsenic and cadmium; the target risk used for each was 5×10^{-8} (for a total risk of 1×10^{-7}) and 5×10^{-5} (for a total risk of 1×10^{-4}). Chromium was not included in the calculation of the target risk for reasons previously stated. The soil concentrations that would produce an entrainable dust concentration that could result in the target cancer risk level for each constituent are reported in Table 3-7. Excess lifetime cancer risks were calculated from ingestion of dusts through the inhalation pathway identified in the PHEA. The excess lifetime cancer risk was estimated as 1×10^{-6}, driven solely by arsenic. A cleanup concentration was not calculated for this pathway because the target concentration for direct ingestion would eliminate the potential risk through this pathway.

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Cardinal

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Chapter 4
PROBLEM DEFINITION

This chapter provides additional information concerning present conditions at the Warm Springs Ponds Operable Unit and the specific public health and environmental problems to be addressed by remedial actions. Eight environmental and human health problems are identified and discussed, from which the feasibility study develops site objectives (Chapter 5) and remedial action alternatives (Chapters 6 and 7). The identified problems derive from the results of the remedial investigations summarized in Chapter 2; applicable or relevant and appropriate requirements summarized in Chapter 3 (and detailed in Appendix B); and the public health and environmental assessment summarized in Chapter 3 (and presented in Appendix A). The conclusion of this chapter discusses the relationship between the problems at the Warm Springs Ponds Operable Unit and those existing within the remainder of the Silver Bow Creek Site.

ENVIRONMENTAL AND HUMAN HEALTH PROBLEMS

The existence of environmental and human health problems directly correlates with noncompliance with applicable or relevant and appropriate requirements (ARARs), or unacceptable health or environmental risks where ARARs are not available. To the extent that compliance with ARARs is achieved under the remedial action alternative selected, the concerns identified in this chapter should be addressed.

The eight problems can be described in terms of four media: pond bottom sediments, surface water, tailings deposits and contaminated soils, and groundwater.

Two problems are associated with the pond bottom sediments:

- Floods affecting pond stability--a flood could cause the pond berms to fail and thus release the pond bottom sediments.

- Earthquakes affecting pond stability--an earthquake could cause the pond berms to fail and thus release the pond bottom sediments.

There are four problems associated with surface water:

- The tailings in and along the Mill-Willow Bypass are a source of sudden high concentrations of dissolved metals in the bypass channel during runoff events and cause fishkills in the bypass and immediately downstream in the Clark Fork River.

- Chronic dissolved metals loads under normal flow conditions in Mill, Willow, and Silver Bow Creeks that exceed water quality standards for protection of aquatic life.

- Erosion of tailings located along the Mill-Willow Bypass into the Clark Fork River during floods.

- Erosion of tailings from upstream reaches of Silver Bow Creek during floods and transport through the operable unit to the Clark Fork River.

The major problems with tailings deposits and contaminated soils are human exposure to the surface contamination through both inhalation and ingestion, the absence of vegetation, and the potential for severe impact to the terrestrial ecosystem in the event of a catastrophic flood. The problem with groundwater is the contamination present in

the groundwater area below the Pond 1 berm, and the groundwater's effects on potential human use and on environmental receptors.

MEDIA 1--POND BOTTOM SEDIMENTS

Pond Stability--Floods

As noted in the preceding chapter, the Montana Department of Natural Resources and Conservation (MDNRC) dam safety rules control the minimum level of flood protection for the design of dams within the State of Montana, and therefore these rules apply to the Warm Springs Ponds. Based on a 1978 inspection by the U.S. Army Corps of Engineers, the Warm Springs Ponds are classified as high hazard dams.[1] For dams classified as high hazard, DNRC dam safety rules require the outlet control structures to be able to safely pass certain design floods, which are dictated by the amount of water impounded and the height of the dam. For the Warm Springs Ponds, the rules require the outlet structures to pass the following design floods without overtopping the berms:

Pond 1--0.2 probable maximum flood (PMF)
Pond 2--0.3 PMF
Pond 3--0.5 PMF

The flood model study, described below, indicated that if no improvements are made, the ponds would likely be damaged during these design floods. Hence, according to the ARARs determination made by the State of Montana and the USEPA, unless the remedy selected provides for complete removal of

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[1] U.S. Army Corps of Engineers, 1979. Dam Safety Inspection, Warm Springs Ponds Tailings Dams and Yankee Doodle Tailings Dam Project.

the pond system, the pond system requires modification, at a minimum, to meet the MDNRC dam safety rules. Moreover, since the dam safety rules are established primarily for dams containing only water and not contaminated sediments, additional measures beyond those required by the dam safety rules may be necessary to prevent the release of the pond sediments.

Flood studies, yielding similar conclusions, have recently been completed for the Silver Bow Creek drainage by ESA Geotechnical Consultants[2] and CH2M HILL.[3]

In the study conducted by CH2M HILL, hydrographs and peak flows were calculated for the 10-, 25-, and 100-year floods, and the probable maximum flood. The floods modeled represent some of the standard flood frequencies that are used for various purposes in engineering design. The PMF was included in the modeling because it is a standard design flood considered in dam stability studies. No specific return intervals are associated with probable maximum floods, with their magnitude being determined by the most severe hydrometeorological conditions at the site, rather than an extrapolation of standard analyses of historical data.

The CH2M HILL report included a map that showed inundated areas for the 100-year flood (Figure 4-2). For this study, flood inundation maps were prepared that show flooded areas during a 25-year flood, a 1/2 PMF, and a PMF (Figures 4-1, 4-3, and 4-4, respectively).

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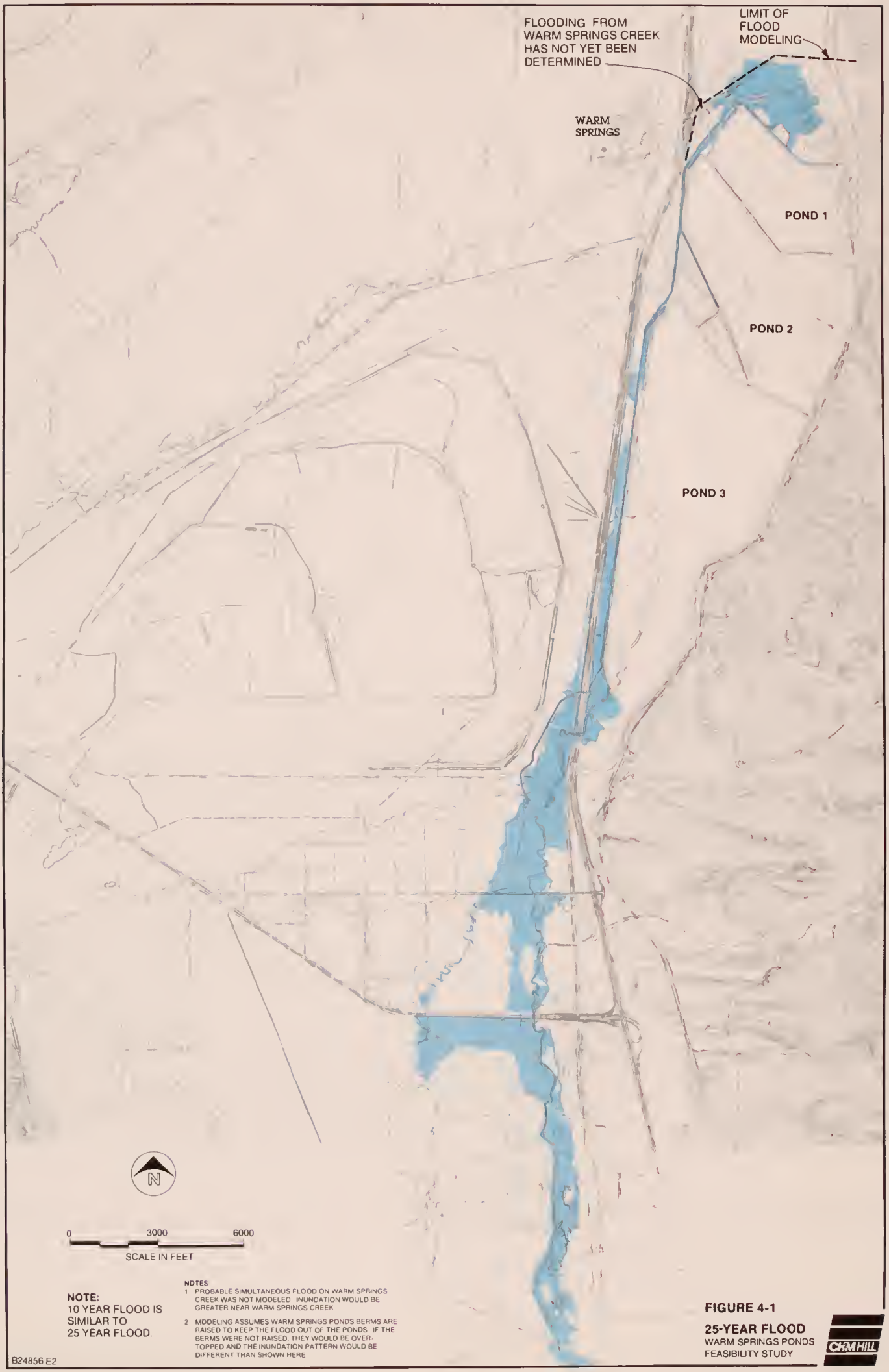
2 ESA Geotechnical Consultants, 1987. The Mill-Willow Bypass Channel/Warm Springs Ponds Systems: Flood Studies and Conceptual Design Modifications. Prepared for the Anaconda Minerals Company, Fort Collins, Colorado.

3 CH2M HILL, 1988. Silver Bow Creek Flood Modeling Study. Prepared for the State of Montana Department of Health and Environmental Sciences, Helena, Montana.



NOTE:
10 YEAR FLOOD IS SIMILAR TO 25 YEAR FLOOD.

NOTES
1 PROBABLE SIMULTANEOUS FLOOD ON WARM SPRINGS CREEK WAS NOT MODELED. INUNDATION WOULD BE GREATER NEAR WARM SPRINGS CREEK
2 MODDELING ASSUMES WARM SPRINGS PONDS BERMS ARE RAISED TO KEEP THE FLOOD OUT OF THE PONDS. IF THE BERMS WERE NOT RAISED, THEY WOULD BE OVER-TOPPED AND THE INUNDATION PATTERN WOULD BE DIFFERENT THAN SHOWN HERE

FIGURE 4-1
25-YEAR FLOOD
WARM SPRINGS PONDS
FEASIBILITY STUDY

CH2M HILL

B24856 E2

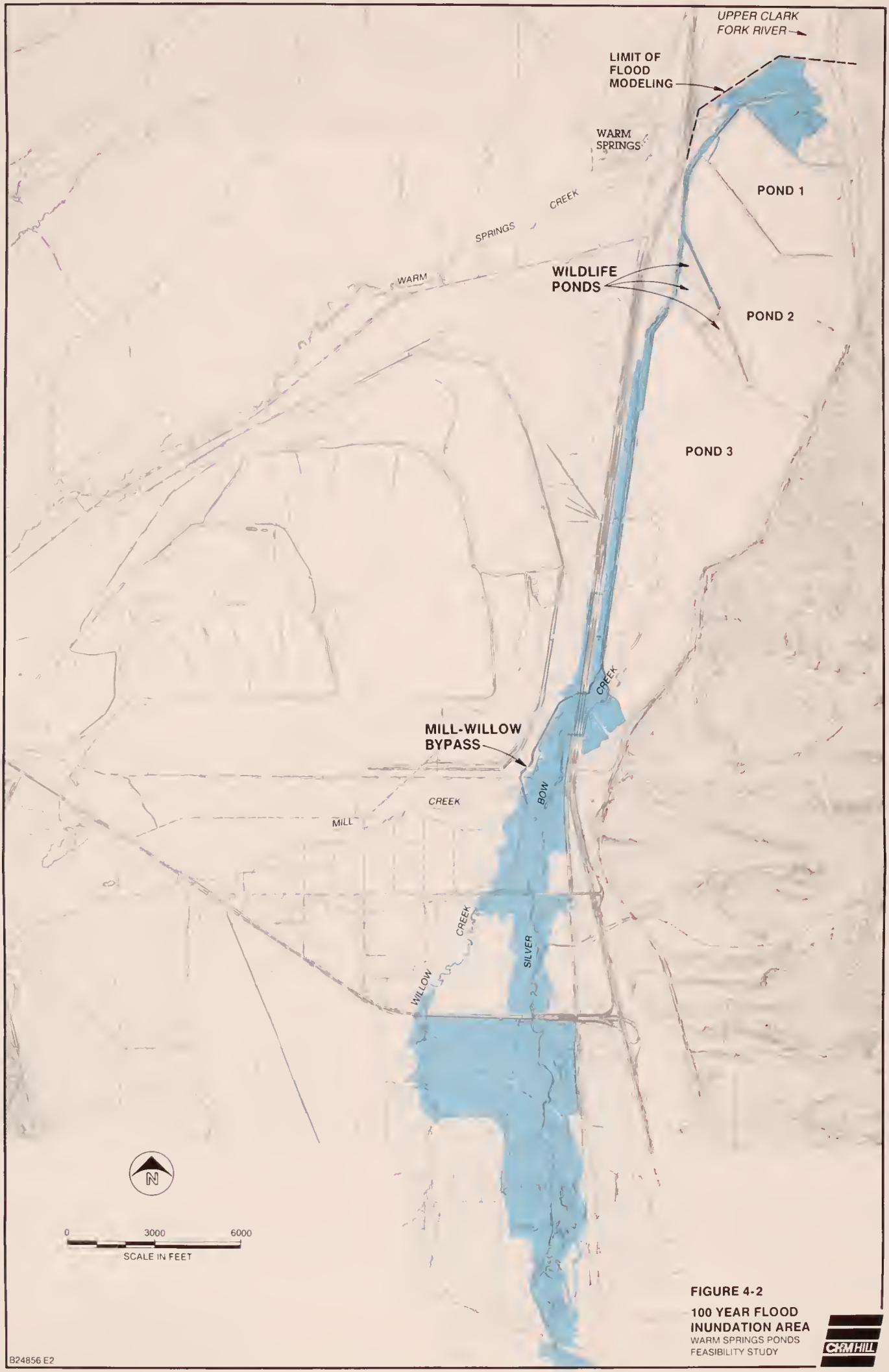
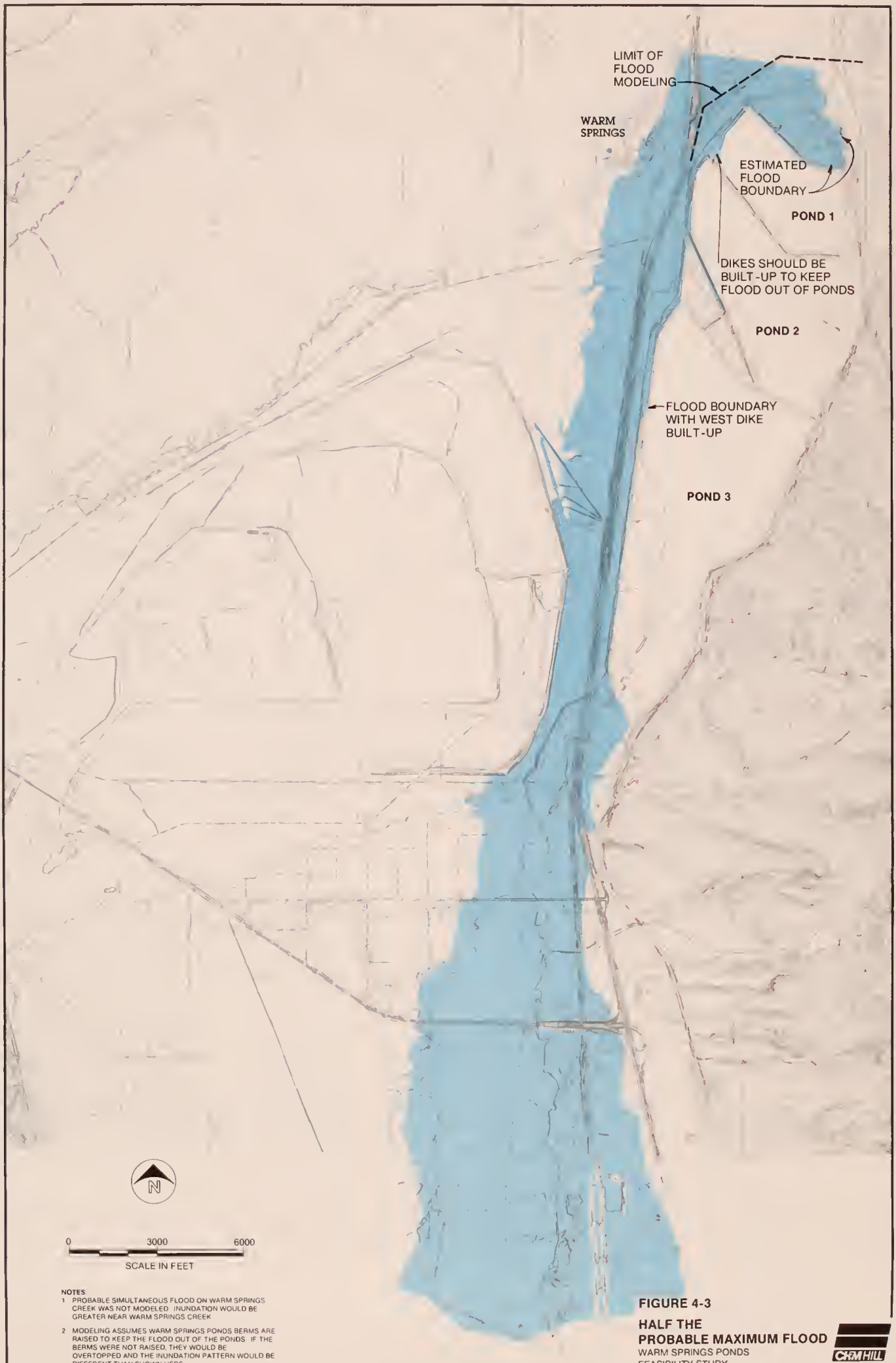


FIGURE 4-2

100 YEAR FLOOD INUNDATION AREA
WARM SPRINGS PONDS
FEASIBILITY STUDY

CH2M HILL

B24856 E2



NOTES:
1. PROBABLE SIMULTANEOUS FLOOD ON WARM SPRINGS CREEK WAS NOT MODELED. INUNDATION WOULD BE GREATER NEAR WARM SPRINGS CREEK.
2. MODELING ASSUMES WARM SPRINGS PONDS BERMS ARE RAISED TO KEEP THE FLOOD OUT OF THE PONDS. IF THE BERMS WERE NOT RAISED, THEY WOULD BE OVERTOPPED AND THE INUNDATION PATTERN WOULD BE DIFFERENT THAN SHOWN HERE.

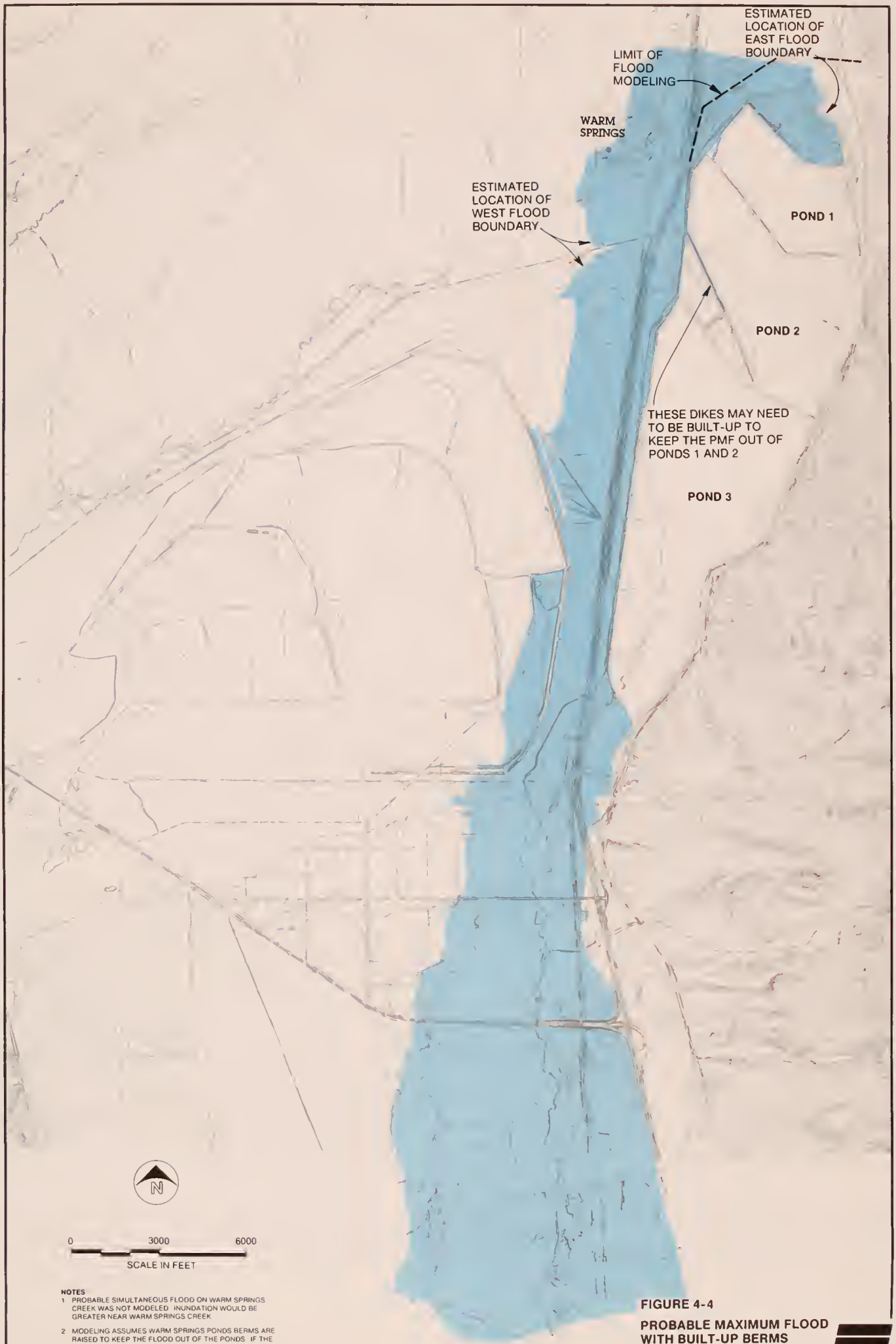
B24856 E2

FIGURE 4-3

HALF THE PROBABLE MAXIMUM FLOOD

WARM SPRINGS PONDS
FEASIBILITY STUDY

CH2M HILL



NOTES
1 PROBABLE SIMULTANEOUS FLOOD ON WARM SPRINGS CREEK WAS NOT MODELED INUNDATION WOULD BE GREATER NEAR WARM SPRINGS CREEK
2 MODELING ASSUMES WARM SPRINGS PONDS BERMS ARE RAISED TO KEEP THE FLOOD OUT OF THE PONDS IF THE BERMS WERE NOT RAISED, THEY WOULD BE OVERTOPPED AND THE INUNDATION PATTERN WOULD BE DIFFERENT THAN SHOWN HERE

B24856 E2

FIGURE 4-4

PROBABLE MAXIMUM FLOOD WITH BUILT-UP BERMS
WARM SPRINGS PONDS
FEASIBILITY STUDY

CH2M HILL

The results of the flood studies and knowledge of the existing conditions of the berms that create the Warm Springs Ponds indicate that the berms are susceptible to overtopping failure during flood events in Silver Bow Creek and the east side drainages. It was beyond the scope of this study to model in detail the failure scenarios likely to occur for the ponds, but based on calculated flow velocities near the berms, it is likely that a 100-year flood, and perhaps floods of less intensity, would cause extensive damage and possible failure of the berms. This would lead to releases of contaminants from the ponds and associated health risks and environmental damage. Much larger floods could result in a general failure of the pond berm system, which would have devastating effects on the Clark Fork River because of the release of a significant portion of the contaminated pond bottom sediments.

The ponds are also susceptible to damage by high runoff from the hills to the east. A probable maximum precipitation event (i.e., the largest expected rainfall event) in the eastern drainages could cause overtopping failure of the berms that create Pond 1, with resultant transport of the pond bottom sediments into the Clark Fork River. Pond 1 has a barely sufficient capacity to contain a 0.2 PMF precipitation; remedial actions in Pond 1, such as capping, could reduce this storage capacity below the level required to contain a 0.2 PMF runoff/precipitation event.

Pond 2 has sufficient storage capacity to contain runoff from a 0.3 PMF event from the hills to the east. Pond 3 has sufficient storage capacity to contain a one-half probable maximum runoff/precipitation event from the hills to the east without overtopping. However, even if the Ponds 2 and 3 berms did not fail due to the overtopping, high runoff

could scour some of the finer sediments from the bottoms of the ponds and wash them out of the ponds into the Clark Fork River.

Damage to the berms from either a major flood on Silver Bow Creek or runoff from the eastern hills could result in at least partial release of the estimated 19 million cubic yards of pond bottom sediments. The distribution of the pond bottom sediments is about 2.9 million cubic yards in Pond 1, 4.9 million cubic yards in Pond 2, and 11.2 million cubic yards in Pond 3. The environmental effects of a release of the sediments could vary greatly, depending on the total volume of the release, the rate of the release, the flow rate of the flood during the release, and other factors.

A release of a small portion of the sediments and tailings during the peak of a large flood might not have a significant or persistent impact on the aquatic environment downstream; the contaminants would be diluted and dispersed over a large area of the Clark Fork River. On the other hand, release of a large fraction of these solids during the latter stages of a flood, when the flows are receding, could leave large areas covered with thick deposits of sediments. Such a release would likely damage fish populations and aquatic habitat along the upper Clark Fork River. These deposits could also be a source of human exposure to metals if the material were deposited in areas of human population or recreation areas. Remediation of the damage done by release of the sediments would be extremely difficult and expensive.

Pond Stability--Earthquake

The Warm Springs Ponds are located within the northern section of the Intermountain Seismic Belt, which is a zone of major earthquake activity within the North American tectonic plate. At least 230 earthquakes with magnitudes greater than 4.0 have occurred at epicenters within 187 miles of the Warm Springs-Butte area during the last 107 years of recorded earthquakes.[4] The largest of these were the 1958 Hebgen Lake, Montana, earthquake (magnitude 7.1), and the 1983 Borah Peak, Idaho, earthquake (magnitude 7.3). These were located approximately 120 and 160 miles from the site, respectively.

The MDNRC dam safety rules require that if a dam is in a region subject to earthquakes, the dam must be designed to withstand the most severe earthquake that can be reasonably anticipated under the currently known geologic and tectonic framework. This design earthquake is known as the maximum credible earthquake (MCE).

The ground shaking during an earthquake can cause berms that are not adequately designed and constructed for such events to flow like a liquid, slumping and releasing the water and semisolids behind them. This phenomenon is known as liquefaction. Earthquakes can also cause seiches, that is, sloshing of the water in a pond (wave action) that can overflow or erode berms, thus causing failure. Again, it was beyond the scope of this study to explore probable earthquake failure scenarios in detail. But a review for this study of previous studies of the ponds and what is known of the

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[4] International Engineering Company (IECO), 1981. Geotechnical and Hydrologic Studies of the Warm Springs Tailings Ponds, Anaconda, Montana. Prepared for the Anaconda Copper Company, Denver, Colorado.

construction of the Warm Springs Ponds berms shows that berms are not strong enough to withstand even a moderate earthquake.

A study of the berms by IECO determined that they were likely to fail in an earthquake less than the maximum credible earthquake.[5] That study considered only the east-west berms that divide the ponds and did not examine the stability of the almost 4-mile-long series of north-south berms along the western edge of the ponds.

Preliminary results from a more recent study of the berms, being conducted by ESA for the Anaconda Minerals Company, also indicate that the berms are susceptible to failure during an earthquake. However, based on additional information on the materials of construction, that study concluded that the berms are less susceptible to liquefaction failure than the IECO study assumed.

A review of information in these studies regarding the embankment materials confirms that the east-west and north-south berms are likely to fail in a moderate-to-severe earthquake; the likelihood of failure appears to be greater than reported by IECO. This was determined by a preliminary stability evaluation performed for this study, which indicated that the downstream slopes of the berms have potential to fail at accelerations from 0.05 to 0.07 g (g is the standard symbol for the acceleration of gravity). For comparison, in 1981, IECO determined that the acceleration at Warm Springs Ponds during a maximum credible earthquake could be as high as 0.23 g.

It is important to stress the preliminary nature of these determinations. If the selected remedial alternative for

[5] Ibid.

the Warm Springs Ponds Operable Unit includes stabilizing the berms against earthquakes, it will be necessary during the design investigation to reevaluate IECO's findings. This reevaluation should be in light of improvements in the analytical methods for estimating maximum credible earthquakes and ground motion since 1981, and in light of earthquake activity in the Intermountain Seismic Belt since 1981 (notably, the magnitude 7.3 Borah Peak, Idaho, earthquake). The results from an updated seismotectonic study would be used in designing and upgrading the berms.

Failure of the upstream slopes (faces) of the berms was not examined in this study because information on the materials and construction of the upstream slopes was not available. The possible need for stabilization of the upstream slopes is not considered in the conceptual designs (Chapter 7) or the cost estimates (Chapter 8) for this study. During the remedial design investigation, the potential for upstream slope failure will have to be investigated.

Failure of the berms from an earthquake could result in at least partial release of the contents of the ponds. The tailings and sediments in the ponds are sufficiently liquid that they could migrate a considerable distance from the ponds. Although it has not been determined that the tailings and sediments in the Warm Springs Ponds would experience spontaneous liquefaction, this is a process that has been observed in seismically induced failures of other tailings ponds. If this process did occur, the tailings and sediments could flow for miles, contaminating a large area downstream of the ponds. The tailings and sediments occur in layers in the ponds (see Chapter 2). Some of the materials in the layers would be more susceptible to spontaneous liquefaction than other materials. The probable shear stress behavior of the entire mass of tailings and

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sediments, as layered in the ponds, was not modeled in this study. This type of modeling was not completed because such an analysis would serve only to refine the distance the sediments would travel and the area impacted by the release. The area contaminated by a berm failure could be extensive, especially for Ponds 2 and 3, even without spontaneous liquefaction of the pond bottom sediments.

If the berm on the north side of Pond 1 failed, and if the tailings spontaneously liquefied, the tailings and sediments could flow a long way from the pond. The tailings and sediments in Pond 1 may be less susceptible to liquefaction because they appear coarser than the sediments in Ponds 2 and 3, and because they are partially dewatered due to the inactive state of the pond. If the berm on the west side of Pond 1 failed, a portion of the tailings and sediments would flow into the Mill-Willow Bypass. The flows in the bypass could then carry some of the tailings and sediments into the Clark Fork River.

The Pond 2 berms are also susceptible to failure. If the north (east-west) berm failed, the water and more-liquid sediments in Pond 2 would spill into Pond 1. Pond 1 could hold some of the release from Pond 2, if it did not itself fail due to the earthquake. But it is likely that a substantial fraction of the released sediments would not be contained in Pond 1 and would spread out over a large area below the Pond 1 berm.

If the berm on the west side of Pond 2 failed, a large amount of the tailings and sediments could be released into the Mill-Willow Bypass. The water in Pond 2--about 270 million gallons (860 acre-feet)--varies in depth to approximately 4 feet. This amount of water, leaving the pond through a breach in the berm, could further damage the berm

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and scour out tailings and sediments as it left the pond. Once released, the flows in the Mill-Willow Bypass could carry the sediments to the Clark Fork River. The tailings could also spontaneously liquefy and travel miles with or without the aid of the flows in the bypass and the Clark Fork River.

The largest potential releases of sediments would be expected if either the north or the west berm of Pond 3 failed. Pond 3 contains approximately 1.5 billion gallons (4,800 acre-feet) of water and 11.2 million cubic yards of sediments. The water, tailings, and sediments in Pond 3 could flow into the Mill-Willow Bypass or they could cascade into Ponds 2 and 1, neither of which has sufficient capacity to contain them. This could result in a nearly complete failure of the pond system, resulting in large releases covering extensive areas to the north and/or west of the ponds.

Whichever failure scenario occurred for Pond 3, a major release of the tailings and sediments from the ponds would result. The release would not be diluted, as would a release during a flood-caused failure. Cleaning up the release and returning the sediments to the ponds would be extremely expensive and difficult.

MEDIA 2--SURFACE WATER

There are four major problems associated with surface water and exceedances of water quality standards near the Warm Springs Ponds:

- Tailings and metal salts in the Mill-Willow Bypass contribute high metals concentrations to the bypass and the Clark Fork River during thunderstorms.

This has caused several major fishkills over the last few years.

- Dissolved and nondissolved metal loads are carried downstream to the Warm Springs Ponds area via Silver Bow Creek, Mill Creek and Willow Creek. Due to current level of treatment of Silver Bow Creek in the Warm Springs Ponds and no treatment of Mill and Willow Creeks, the combined flows of these three creeks often exceed chronic ambient water quality standards in the bypass below the Pond 2 outlet.

- Tailings deposits in the Mill-Willow Bypass erode and are transported to the Clark Fork River, especially during higher flow conditions. These tailings can contribute to both chronic and acute exceedances of the ambient water quality standards in the Clark Fork River.

- Tailings from the upper reaches of Silver Bow Creek can be eroded and transported through the Warm Springs Ponds Operable Unit and subsequently to the Clark Fork River. There the tailings can contribute to both chronic and acute exceedances of the ambient water quality standards.

Fishkills in The Mill-Willow Bypass

There have been five documented fishkills associated with the Mill-Willow Bypass since 1983. They occurred on August 9, 1983; August 2, 1984; July 3, 1987; May 27, 1988; and July 13, 1989, and the first four are documented in Montana

Department of Fish, Wildlife, and Parks memoranda.[6] Data from the most recent fishkill were not yet available when this report was written.

All five fishkills followed a similar pattern. They were associated with locally intense thunderstorms in the Warm Springs Ponds area, usually after extended dry periods. The fishkills started in the Mill-Willow Bypass and extended down the Clark Fork River to various extents. In the 1984 event, over a thousand dead fish were observed in a 15- to 20-mile stretch of the Clark Fork River. Over 5,000 dead fish were reported following the July 1989 event.

The fishkills have been linked to high concentrations of copper in the water; zinc concentrations and low pH levels may also be factors in fish mortality. Obtaining data to demonstrate exceedances of the acute ambient water quality standards is difficult for short duration events such as metal releases associated with local thunderstorms. However, some data were obtained by the Montana Department of Fish, Wildlife, and Parks for the four documented fishkills including metal concentrations and pH in the stream and copper and zinc concentrations in gill tissue. The May 1988 event did not cause fishkills outside of the Mill-Willow Bypass as it was a smaller event than the three previous ones. However, the data collected for this event were more complete within the Mill-Willow Bypass than for the previous events and are described in detail in the following paragraphs.

Table 4-1 lists copper concentrations detected in the bypass over time for the fishkill of May 27, 1988, beginning near

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6 Montana Fish, Wildlife and Parks Memoranda: Glen Phillips to File, August 31, 1983; Dick Pedersen and Glenn Phillips to File, August 7, 1984; Glenn Phillips to File, August 23, 1984; Glenn Phillips to File, September 5, 1984; Glenn Phillips to Steve Pilcher, July 22, 1987; Glenn Phillips to Larry Peterman, August 11, 1987; and File Data, 1988.

Table 4-1
MILL-WILLOW BYPASS WATER QUALITY DURING AND AFTER A THUNDERSTORM
MAY 27 AND 28, 1988

Location	Date (time)	pH	Total Alkalinity (as $CaCO_3$)	Hardness (as $CaCO_3$)	Metal Concentration (ug/l) Cu	Zn
Mill-Willow near hog hole	May 27 (3:50 p.m.)	4.79	1.2	160	2,480	3,250
Mill-Willow near Pond 2	May 27 (4:00 p.m.)	5.52	7.8	164	1,800	2,460
Clark Fork below Warm Springs bridge	May 27 (4:30 p.m.)	7.24	61.0	133	70	120
Mill-Willow near Pond 2	May 27 (5:15 p.m.)	7.18	38.0	112	280	320
Mill-Willow near Pond 2	May 27 (6:10 p.m.)	7.25	45.0	109	100	90
Mill-Willow near Pond 2	May 28 (8:45 a.m.)	7.35	50.0	107	30	60

Note: Average values for the Mill-Willow Bypass are copper 37 ug/l and zinc 72 ug/l (RI Phase I data).

Ambient water standards to protect aquatic life for copper are 18 ug/l (acute) and 12 ug/l (chronic); and for zinc are 120 ug/l (acute) and 110 ug/l (chronic).

Source: Fish and Wildlife Service data.

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the end of the thunderstorm. The copper concentrations recorded on May 27 and 28 are well above the acute ambient water quality standards for freshwater aquatic species (18 ug/l) for a hardness of 100 mg/l. Actual concentrations in the Mill-Willow Bypass were as high as 2,480 ug/l. The rapid decline of the copper concentrations as the storm progressed and passed indicates that the high levels were a transient event, associated with the storm.

Table 4-2 lists the metal concentrations in the gills of dead or moribund fish collected during the May 1988 fishkill. The high levels for copper and zinc indicate the fish absorbed significant amounts of these metals over a short period of time; fish would die at much lower levels if the concentrations built up over time.

The rapid elevation and dissipation of the metals concentrations in the water during storm events indicate that contaminants are derived from a readily available source of highly soluble compounds, i.e., metal salts. A source of such salts has been identified along the Mill-Willow Bypass. During extended dry periods, salts of copper and zinc form through the evaporation of soil moisture on the tailings deposits that exist along the bypass. As described in Chapter 2, the remedial investigation determined that there are approximately 21 acres of exposed tailings deposits along the bypass with a corresponding volume of approximately 76,000 cubic yards.

The copper salts are clearly visible during warmer months as blue- and green-colored surface deposits. The salts are not apparent on soils other than the exposed tailings.

There are two possible mechanisms for the formation of the soluble salts along the bypass. The postulated mechanism is the direct formation of soluble species from the tailings

Table 4-2
METALS CONCENTRATIONS IN GILLS OF FISH
COLLECTED FROM THE MILL-WILLOW BYPASS,
MAY 27 AND 28, 1988

Species	Metal Concentration Dry Gill Tissue (ug/g) Copper	Zinc
Brown trout	49	225
Brown trout	92	158
Brown trout	22	244
Longnose suckers[a]	228	184
Longnose suckers[a]	163	143
Longnose suckers[a]	77	116
Longnose suckers[a]	164	170
Longnose suckers[a]	155	166
Longnose suckers[a]	106	131
Whitefish[a]	73	125

[a]Composite gill samples from two fish were combined.

Note: Fish had just been killed or were severely stressed at the time they were collected.

Source: Fish and Wildlife Service data.

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deposits through oxidation. The appearance of the visible salts only on the tailings deposits argues for this as the probable mechanism. An alternative mechanism is formation of the salts due to wicking up and evaporation of contaminated groundwater from beneath the surface, which would leave behind metal salts. However, the groundwater along the bypass has been sampled and tested for metals, and the results indicate that the groundwater is not significantly contaminated with copper or zinc. Table 4-3 lists the analytical results for groundwater samples taken along the bypass (see Figure 2-13 for the sampling points). In addition, the formation of the salts only on the tailings argues against the groundwater as their source, because wicking and evaporation of groundwater would lead to a more uniform distribution of the salts at the surface.

The sediments in and along the bypass have been analyzed for copper and zinc. The results are presented in Table 4-4. High levels of the two metals, relative to the other sediments in the bypass, were detected in the metallic salts.

The copper sulfate that would result from oxidation of copper sulfide in the tailings would be readily soluble in water. Though no data are available on the copper (or zinc) species of the visible salts, they have been determined to be readily soluble during laboratory tests to determine their metal content.

The postulated mechanism for the fishkills is that the rain water dissolves the metal salts and washes them into the bypass, resulting in the fishkills. The elevated levels of metals detected in the gills of dead fish suggest that the fish died from the metal contaminants.

Table 4-3
CONTAMINANT CONCENTRATIONS IN GROUNDWATER
ALONG THE MILL-WILLOW BYPASS

Well Sampled[a]	Date	Copper[b] (ug/l)	Zinc[b] (ug/l)
07-D	1/15/88	8U	38
07-S	1/15/88	15	60
08-D	12/29/87	8U	36J
08-D (R)	12/29/87	8U	41J
08-S	12/29/87	8U	22J
15-D	1/20/88	8U	28J
15-D (R)	1/20/88	8U	26
15-S	1/20/88	8U	27J

[a](R) = Replicate sample.
U = Not detected; the detection limit is listed.
J = The value is useful only as an estimate because quality control criteria were not met.
D = Well in a deep aquifer.
S = Well in a shallow aquifer.

[b]Ambient water standards to protect aquatic life for copper are 18 ug/l (acute) and 12 ug/l (chronic); and for zinc are 120 ug/l (acute) and 110 ug/l (chronic).

Note: Sampling points are shown on Figure 2-8.

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Table 4-4
MILL-WILLOW BYPASS SEDIMENT DATA
BY MATERIAL TYPE

Material Type	Copper (mg/kg)	Zinc (mg/kg)
Type 1 Sand		
Average Concentration	1,103	1,459
Range	371 - 3,900	431 - 3,600
Type 2 Sand		
Average Concentration	534	780
Range	19 - 1,690	46 - 2,130
Type 3 Sand		
Average Concentration	1,400	1,701
Range	206 - 4,730	205 - 5,330
Silt		
Average Concentration	1,874	3,023
Range	468 - 3,040	712 - 6,760
Metallic Salts		
Average Concentration	19,680	21,266
Range	2,150 - 66,300	524 - 64,300

Notes:

Type 1 Sand--Sand, brown, very fine to fine grained, moderately well sorted, occasionally silty.

Type 2 Sand--Sand, brown to light brown, medium to coarse grained, poorly sorted, occasionally silty.

Type 3 Sand--Sand, yellow-brown to orange, very fine to fine grained, moderately well sorted. Typically associated with visible tailing deposits.

Silt--Silt, dark brown to yellow-brown, sandy, typically abundant root fragments. Generally associated with good vegetation growth. Sometimes occurs within a vegetation mat.

Metallic Salts--Bluish-green to orange material, crystalline character, typically forms a crust over sand material. Commonly associated with tailing flats.

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In order to test the possibility of rain dissolving soluble metal species from tailings, an experiment was performed. At a site several miles upstream from the bypass, where large tailings deposits exist, sprinklers were run for 4 hours after an extended dry spell to simulate a summer rain event. The resultant runoff was collected and analyzed for both total and dissolved copper. The analyses detected dissolved copper concentrations of 640,000 ug/l and total copper concentrations of 930,000 ug/l in the runoff. These results indicate that 70 percent of the copper washed from the tailings was in soluble forms; the remainder was particulate-borne. These runoff concentrations would be diluted when combined with the surface water in the channel. However, even with a large dilution in the stream, these levels far exceed the acute toxicity standards (18 ug/l) for copper in freshwater organisms.

It is probable that metal-contaminated particulates contributed to the fishkills as well. During dry spells, airborne dust may transport metal-contaminated particulates to areas in and along the bypass. Particulates have been detected in the gills of the dead and moribund fish collected after the fishkills. The water analyses reported in Table 4-1 are for total recoverable copper and therefore include both dissolved copper and copper-contaminated particulates. However, the results in Table 4-4 indicate that the silt (finest) fraction of the sediments contains levels of copper only one-tenth as high as the levels in metallic salts. Therefore, the particulate contribution to the fishkills is anticipated to be far less than the contribution from dissolved forms of copper and zinc.

In summary, while transient phenomena such as the observed fishkills are difficult to study and even more difficult to model, the evidence available at this time points to the visible salts on the tailings deposits as the primary cause of the fishkills.

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Metal Loads in the Stream Flows

Silver Bow Creek, Mill Creek, and Willow Creek contain detectable levels of metals, mostly copper, arsenic, lead, and zinc. A summary of the average copper and zinc concentrations from the Phase I remedial investigation for selected surface water sampling sites is shown in Table 4-5. (Tables 2-8 through 2-11 give a detailed summary, for all metals detected, of the surface water quality in the operable unit during the remedial investigation.) For example, on the average, the inflow to the ponds (SS-19), the discharge from Pond 2 (PS-12), and the combined flows of Mill and Willow Creeks (SS-18) exceeded the chronic ambient water quality standard for copper. The standard was exceeded in 100, 70, and 60 percent of the samples in the Phase I remedial investigation for SS-19, PS-12 and SS-18, respectively.

The Mill-Willow Bypass was constructed to route the comparatively cleaner Mill and Willow Creek flows around the ponds and to the Clark Fork River without mixing with the comparatively more contaminated Silver Bow Creek flow. However, recent data indicate that, although Mill and Willow Creeks are cleaner than Silver Bow Creek, they still contribute a significant portion of the total amount of dissolved metals reaching the Clark Fork River. For example, based on the average copper concentrations and averages flows at SS-18 and PS-12 for the Phase I remedial investigation data, the copper load of the combined flows of Mill and Willow Creeks (SS-18) were in magnitude, approximately 30 percent of the load for the discharge from Pond 2 (PS-12).

The Warm Springs Ponds system treats the Silver Bow Creek flow by three types of processes: 1) physically settling out suspended solids, such as tailings, and precipitating dissolved metals through 2) biological and 3) chemical processes. Thus, metal contaminants from Silver Bow Creek, whether suspended or dissolved, are removed to some degree

Table 4-5
COMPARISON OF AVERAGE METAL CONCENTRATIONS FOR PHASE I
SURFACE WATER SAMPLES TO CHRONIC WATER QUALITY STANDARDS

	Average Concentrations Total Metals-Phase I RI mg/l			Chronic Water Quality Standard Hardness 100 mg/l		Hardness 200 mg/l	
	Copper	Zinc	Hardness	Copper	Zinc	Copper	Zinc
Silver Bow Creek Warm Springs Ponds Inflow (SS-19)	0.170	0.415	148	0.012	0.110	0.021	0.190
Discharge from Pond 2 (PS-12)	0.050	0.151	177	0.012	0.110	0.021	0.190
Combined Flow of Mill and Willow Creeks at Bypass Entrance (SS-18)	0.031	0.045	129	0.012	0.110	0.021	0.190

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by the pond system. Mill and Willow Creeks are diverted around the pond system in the Mill-Willow Bypass and receive no treatment.

Settling of suspended solids occurs simply as a result of decreased flow velocities in the ponds compared to the velocities in the creek channel. The removal of dissolved metals occurs because of photosynthetically induced chemical precipitation, chemical precipitation (during the winter), and uptake of metals by and subsequent settling of aquatic plants. The effectiveness of the ponds is enhanced by the addition of lime during colder months when the amount of light available for photosynthesis and biological activity is diminished.

Without the treatment currently provided by the ponds system, the chronic ambient water quality standard for copper (12 ug/l for a hardness of 100 mg/l), for example, would be regularly exceeded in the upper reach of the Clark Fork River (more than 75 percent of the time). However, even with the pond system's current treatment of the Silver Bow Creek flow, the water quality standards are frequently exceeded as described previously (see Chapter 2). The dissolved metals in the three creeks ultimately contribute to the chronic exposure to fish in the Clark Fork River.

Until the upstream sources of the contaminants are addressed, the treatment currently provided by the pond system will need to be continued within the existing pond system or in another pond. (The flows are so large that only a pond-type treatment system is practical, see Chapter 6.) In order to meet the surface water ARARs identified in Chapter 3 on a consistent basis, the current system will have to be improved to provide more effective and consistent treatment. (Under some flow conditions, the existing pond system acts as a source of increased contamination rather than affecting net improvement in water quality--see

Chapter 7.) Alternatively, a new pond system of a greater treatment capacity will be required.

Tailings in the Mill-Willow Bypass

Tailings along the Mill-Willow Bypass probably are a combination of deposits that occurred before the construction of the ponds, deposits from Silver Bow Creek floods since the construction of the ponds (high flows are diverted around the ponds rather than being allowed to flow through them), and perhaps some deposits from Willow Creek. The total amount of identifiable tailings in the bypass has been estimated at 79,000 cubic yards. This includes 76,000 cubic yards of exposed tailings deposits and 3,000 cubic yards of tailings with vegetation cover.

It is assumed that these tailings are eroded and transported out of the bypass to the Clark Fork River with higher flow events such as bank-full conditions transporting larger volumes of sediments. Once deposited in and along the banks of the Clark Fork River, they contribute to the contamination that already exists there and may thus contribute to adverse effects to fish. As noted previously, metal-contaminated particulates, such as tailings, may also contribute to fishkills. The specific metals of concern in the tailings are described in Chapter 2 and include copper, zinc, and arsenic.

It is not possible to predict exactly the adverse effects that could result from continued erosion of the bypass tailings and redeposition in and along the Clark Fork River. This is because Warm Springs Creek and the Mill-Willow Bypass converge and form the Clark Fork River at its defined starting point. Thus, any exceedances of the water quality standards in the upper reaches of the Clark Fork River would be a combined effect of the two watersheds. (Warm Springs Creek is also contaminated.)

If the tailings were redeposited along the banks of the Clark Fork River as they are now along the bypass, they might cause or at least contribute to transient exceedances of the water quality standards of the type that now cause fishkills in the bypass. And, of course, the tailings could contribute to the chronic contamination in the river.

Transport of Tailings to the Clark Fork River

The Warm Springs Ponds are 27 river miles from Butte, where most of the mining-related activities occurred that led to the contamination of the entire Silver Bow Creek system. Silver Bow Creek is contaminated along much of those 27 miles, with several large deposits of tailings interspersed with many smaller tailings deposits (see Figure ES-3). Much of these tailings were released into the creek as a (then common) disposal practice and they settled out wherever velocities in the creek decreased. There are also much smaller deposits of tailings along Willow Creek.

The vertical-to-horizontal gradient of Silver Bow Creek flattens from 0.008 as it leaves the canyon 10 miles south of Pond 3, as shown in Figure ES-3, to 0.003 at the headwaters of the Clark Fork River. As the stream velocity slows, the coarser material settles out. Because of this, there are also deposits of tailings along the creek downstream of the canyon (see Figure ES-3). The tailings are being continuously transported down Silver Bow Creek, but the rate of transport depends on the flow conditions in the creek.

Altogether, some 3 million cubic yards of tailings are estimated to exist upstream of the Warm Springs Ponds.[7] These tailings are eroded by flows in Silver Bow, Mill , and Willow Creeks. High flows especially can erode and move large quantities of these tailings. The recent flood study[8] estimated that a 100-year flood on Silver Bow Creek would deliver 100,000 cubic yards (1 acre, 62 feet deep) of sediments to the Warm Springs Ponds. These sediments would consist of both natural soil and sediments, but would include a large amount of tailings. The majority of these eroded tailings would be carried by the rapid flood flow through the operable unit and to the Clark Fork River.

Small scale movements of tailings in Silver Bow Creek (less than 2-year storm events) are currently settled out in the pond system. Calculations performed as a part of this study indicate that the outlet structures of Pond 3 can accept flows up to 600 cubic feet per second (cfs) total, without inducing scour from the bottom of the pond. At flows above 600 cfs, scour of the bottom sediments would likely occur because of the higher water velocities near the pond bottom. This action could result in higher concentrations of metals leaving Pond 3 than entering it. Such scouring is likely in Pond 2 at even lower flow rates due to its very shallow depth and much lower effective volume. Six hundred cfs equates to about a 2-year storm.

Additionally, tailings moving down Mill and Willow Creeks are not routed through the pond system but instead flow

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7 Hydrometrics, 1983. Summit and Deer Lodge Valleys Long-Term Environmental Rehabilitation Study, Butte-Anaconda, Montana, Volume VI, Silver Bow Creek. Prepared for Anaconda Minerals Company, Butte, Montana.

8 CH2M HILL, 1988.

into the Mill-Willow Bypass and on into the Clark Fork River. These flows also carry eroded tailings into the operable unit.

Because of these facts, much of the three million cubic yards of tailings upstream of the Warm Springs Ponds can be expected, based on existing conditions, to reach eventually the Clark Fork River via the Mill-Willow Bypass during high flow events. The continued transport of these tailings to the Clark Fork River contributes to the tailings contamination that already exists in the river. Additional tailings deposits would contribute to increased chronic metal concentrations in the Clark Fork River in the future. The same as tailings eroded from the Mill-Willow Bypass, if deposited along the banks of the Clark Fork River, these tailings could also contribute to transient exceedances of the water quality standards and perhaps fishkills.

MEDIA 3--TAILINGS DEPOSITS AND CONTAMINATED SOILS

Figure ES-1 shows the areas of tailings deposits around the pond system. In addition to these areas, there are soils that contain varying percentages of tailings or that are otherwise metal contaminated. The area of tailings deposits and contaminated soils, as described in Chapter 2, is estimated to be approximately 420 acres with a corresponding volume of 1.9 million cubic yards.

The primary pathways identified for potential human exposure to these contaminants are direct (skin) contact, inhalation of dust from the surface, and incidental ingestion of contaminated media (soil and sediment). The Public Health and Environmental Assessment, which was summarized in the preceding chapter and appears in its entirety in Appendix A, discusses these three exposure routes in detail and the human

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health hazards associated with them. It also discusses risks posed to the environment as a result of the tailings deposits and contaminated soils.

The Public Health and Environmental Assessment describes various scenarios for human exposure to the surface contamination. These are the current residential, current occupational, current recreational, and future residential scenarios. The current residential scenario describes the exposure for those people currently living near the ponds. The current occupational scenario describes the exposures for the current workers at the ponds, and the current recreational scenario presents the exposures for people who use the pond area for recreational purposes. The future residential scenario presents the potential risks for people who might reside within the Warm Springs Ponds Operable Unit in the future.

For the current recreational scenario, the excess lifetime cancer risks associated with the incidental ingestion of exposed sediments is estimated to be 3×10^{-6} for the average exposure conditions, and 4×10^{-5} for maximum plausible exposure conditions. Both of these exposure conditions are described in the Public Health and Environmental Assessment. For the current occupational scenario, the excess lifetime cancer risks are 2×10^{-5} and 2×10^{-4} for average and maximum plausible exposure conditions, respectively. For the future residential scenario the excess lifetime cancer risks are 3×10^{-4} and 2×10^{-3} for the average and maximum plausible risk condition, respectively. In addition to incidental ingestion of exposed sediments, these sediments can be entrained into the air and inhaled. The excess lifetime cancer risk for the current residential scenario is estimated to be 8×10^{-6} for the most plausible condition for inhalation of exposed sediments. This value is based on

data produced from air models, which may overestimate the risk from inhalation, as discussed in Appendix A. Generally, USEPA considers acceptable risks as those from 10^{-4} to 10^{-7}. Hence, the maximum excess lifetime cancer risk identified for the exposed sediments is a problem that must be addressed.

MEDIA 4--GROUNDWATER

As described in Chapter 2, exceedances of primary maximum contaminant levels for cadmium and arsenic were identified in wells located in the shallow sand and gravel aquifer in and below Pond 1. The levels of contaminants in the groundwater downgradient of Pond 1 are given in Table 2-13.

The area of primary maximum contaminant level exceedances in groundwater caused by the pond system is estimated to cover 180 acres. There are two primary reasons why the area of contamination is not more extensive. Most significantly, the pond bottom sediments (tailings and sediments) form a low permeability layer on the bottoms of the ponds, particularly in Ponds 2 and 3. Thus, the contaminated water in the ponds and in the sediments does not leak out and contaminate the groundwater to the degree that it otherwise would. Additionally, upward gradients in the aquifer north of Pond 1, and the interception of the groundwater in that area by the Clark Fork River, have kept the groundwater contamination from spreading very far north of the ponds.

Contamination of the Clark Fork River by groundwater inflow has been estimated based on average flows and contamination levels. The contaminated groundwater discharge to the Clark Fork River is estimated (based on pump tests in wells) to be approximately 1 cubic foot per second, while the average flow in the Clark Fork River is approximately 140 cubic feet

per second. As shown in Table 2-13 for the shallow wells below Pond 1, only cadmium with a value of 3.6 ug/l is above the chronic ambient water quality standard. (At a hardness of 100 mg/l the standard for cadmium is 1.1 ug/l.) Thus, the groundwater impact on the Clark Fork River is small, and indivisible from metals concentrations in the river from other sources.

Because of the potential risk to receptors of the contaminated groundwater, and based on the ARARs analysis by the State of Montana and the USEPA, the exceedances of the maximum contaminant levels in the aquifer is a problem that must be addressed.

RELATION TO THE HEALTH AND ENVIRONMENTAL CONCERNS FOR THE WHOLE SITE

The location of the Warm Springs Ponds Operable Unit in relation to other parts of the Silver Bow Creek Site, as well as other sites in the Clark Fork River Basin, is a significant factor in determining the types and range of alternatives available to achieve a permanent remedy at the operable unit, as required by Superfund. The human health and environmental risks described above can be attributed to contamination that has migrated from upstream areas to the operable unit. The primary mode of the migration has been and continues to be surface water flowing in Silver Bow, Mill, and Willow Creeks. The surface water is itself a contaminated media, but it also functions to transport other media, such as tailings and sediments, to the Warm Springs Ponds. This results in the presence of existing human health and environmental problems at the operable unit, as well as the continued potential for future human health and environmental problems from upstream sources. Accordingly, source control measures in some instances, and migration management

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measures in other instances,[9] are necessary to achieve the statutory mandate of assuring permanent protection of human health and the environment.[10] The following discussion describes the relationships of the eight problems identified at the Warm Springs Ponds Operable Unit to the problems that exist in the remainder of the Silver Bow Creek Site. The effect that this interrelationship might have on the appropriateness of using source control as opposed to migration management measures to achieve remediation are also identified.

POND BOTTOM SEDIMENTS

The flood and earthquake stabilities of the pond berms are unrelated to the problems in the remainder of the Silver Bow Creek Site. The possible approaches for addressing the potential release of the pond bottom sediments presently contained are generally not affected by the approaches that might be taken in the future to remedy the upstream problems. However, the loss of the ponds during a flood or earthquake would have a large, potentially catastrophic impact on the Clark Fork River, possibly as far as the Milltown Reservoir, which is also a Superfund site. The Milltown Reservoir, approximately 145 river miles from Butte, already contains tailings from the Butte area. The potential for a catastrophic failure of the ponds is the primary reason that the Warm Springs Ponds were identified as the first operable unit within the Silver Bow Creek Site to be studied.

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9 40 CFR § 300.68(d). The NCP defines "source control remedial action" as "measures that are intended to contain the hazardous substances or pollutants or contaminants where they are located or eliminate potential contamination by transporting the hazardous substances or pollutants or contaminants to a new location." It defines "management of migration" as "actions that are taken to minimize and mitigate the migration of hazardous substances or pollutants or contaminants and the effects of such migration." 40 CFR § 300.6.

10 CERCLA § 121(b)(1) and (d)(1), 42 USC § 9621(b)(1) and (d)(1).

The fishkills most likely originate from tailings along the Mill-Willow Bypass, and to that extent the solution to the fishkills lies in addressing the problem within the Warm Springs Ponds Operable Unit. However, because additional tailings from upstream areas continue to be deposited in the bypass, a permanent solution of the fishkill problem will require additional cleanup actions upstream. This feasibility study explores means to control the transport of eroded upstream tailings until the upstream tailings deposits are either removed or otherwise controlled, or in case of catastrophic events that may cause upstream cleanups to fail.

The sources of the metal loads in Silver Bow, Mill, and Willow Creeks are upstream of the Warm Springs Ponds. The alternatives explored for this problem in this operable unit feasibility study only address options for managing the migration of these waterborne metal contaminants. Alternatives for cleanup of the sources of the contaminants are not included in this study, but will be considered in later feasibility studies for the upstream portions of the Silver Bow Creek Site.

From the perspective of developing remedial alternatives, it is significant that an average of approximately 100 cubic feet per second of contaminated water from Silver Bow, Mill, and Willow Creeks is constantly flowing into the Warm Springs Ponds Operable Unit. The only feasible means to treat this large flow of contaminated water is in the existing pond system or in a new pond system. This fact restricts the range of alternatives that are technically

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feasible for the Warm Springs Ponds Operable Unit. Alternatives that would disrupt, greatly alter, or eliminate the existing pond system would most likely have to include a new pond system to treat the contaminated stream flows, at least until the upstream sources are controlled. Even if upstream sources are controlled, if upstream remediation cannot reduce the contamination in the creeks to below the levels required by the ARARs, treatment of the creek flows in the pond system may be required over the long term.

Erosion of the tailings currently in the Mill-Willow Bypass into the Clark Fork River is a problem that is contained within the operable unit, and its solution must be based on actions taken in the bypass.

The passage of upstream tailings through the operable unit also presents a problem. The alternatives developed in this study do not include upstream actions to stop the tailings from eroding; they focus on actions that can be taken within the immediate vicinity of the ponds to capture the tailings after they are eroded, but before they reach the Clark Fork River. They do not include actions to stabilize or remove the tailings from the banks of Mill, Willow, and Silver Bow Creeks. These source control actions will be evaluated in later feasibility studies for the upstream portions of the Silver Bow Creek Site.

TAILINGS DEPOSITS AND CONTAMINATED SOILS

The surface contamination in the Warm Springs Ponds Operable Unit originated from flows from the upstream areas. Alternatives that would remove the existing surface contamination must consider that some cleaned areas could be recontaminated with additional tailings carried by subsequent floods, at least until the time that all of the upstream tailings are stabilized or removed. This feasibility study explores

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means to manage the migration of upstream tailings until those tailings are either removed or controlled at their source.

GROUNDWATER

The problem of contaminated groundwater near Pond 1 is independent of the problems that exist outside of the Warm Springs Ponds Operable Unit. Consequently, actions taken to address contaminated groundwater are independent of the actions that might later be taken to address other areas.

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Chapter 5
IDENTIFYING REMEDIAL OBJECTIVES AND GENERAL RESPONSE ACTIONS

This feasibility study develops alternative methods of cleanup for the contaminated media (i.e., pond bottom sediments, surface water, tailings deposits and contaminated soils, and groundwater) of the operable unit. The process of developing these cleanup alternatives for the entire operable unit begins with identifying a range of actions that can be taken. Identifying the range of possible actions consists of six steps: 1) identify remedial action objectives; 2) identify general response actions for each of the contaminated media; 3) identify the area and volume of each of the contaminated media to which each response action may be applied; 4) identify and screen technologies and process options applicable to each general response action; 5) select representative process options; and 6) assemble the representative process options into media-specific actions that represent a range of options, including, as appropriate, treatment, removal, and containment.[1]

To explain the objectives of remediation, this chapter first provides a summary of the legal framework under which remediation must be conducted. This chapter then discusses the first three steps mentioned above. The remaining three steps are described and completed in Chapter 6. In Chapter 7, the media-specific actions, which are conceptual, are developed into more specific actions that could be taken to achieve the remedial goals. In Chapter 8, the media-specific actions are assembled into alternatives for the entire operable unit.

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[1] USEPA, 1988. Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA, (Interim Final, Sept. 1988). Washington, DC. 4-3 to 4-5.

STATUTORY AND REGULATORY REQUIREMENTS

The primary purpose of a feasibility study is to 1) identify a broad range of potential alternatives for remedial action; 2) compare the alternatives to assess their feasibility in terms of effectiveness, implementability, and cost; and 3) evaluate, in detail, several of the most feasible alternatives both individually and against one another. All of this must be accomplished within the framework of Superfund and its implementing regulations prescribing the method for a feasibility study.

Superfund requires selection of a remedial action that is protective of human health and the environment, is cost effective, achieves ARARs, and uses permanent solutions and alternative treatment technologies or resource recovery technologies to the maximum extent practicable.[2] (If several remedial actions are equally effective, the lowest cost action can be selected.) Additionally, Superfund establishes a preference for remedial actions that permanently and significantly reduce the volume, toxicity, or mobility of the hazardous substances, pollutants, and contaminants of concern at each site. The law identifies as the least favored remedial action alternative one in which offsite transport and disposal of hazardous substances or contaminated materials occurs without treatment.[3]

Superfund also emphasizes consideration of 1) the long-term uncertainties associated with land disposal; 2) the goals, objectives, and requirements of the Federal Solid Waste Act; 3) the persistence, toxicity, and mobility of hazardous sub-

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2 CERCLA § 121(b)(1), 42 USC § 9621(b)(1).

3 Id.

stances and their constituents and their propensity to bioaccumulate; 4) short- and long-term potential for adverse health effects from human exposure; 5) long-term maintenance costs; 6) the potential for future remedial action costs if the alternative remedial action selected were to fail; and 7) the potential threat to human health and the environment associated with excavation, transportation, and redisposal or containment.[4] First and foremost, Superfund requires that remedial actions attain a degree of cleanup that "at a minimum...assures protection of human health and the environment."[5]

In addition, for any hazardous substance remaining onsite, the remedial action must attain applicable or relevant and appropriate requirements (ARARs), unless one of six statutory waivers to attainment of ARARs applies.[6] ARARs attainment and human health and environmental protectiveness are threshold requirements for any selected action.

Moreover, federal regulations require that, to the extent possible and appropriate, the feasibility study develop at least one remedial alternative in each of the five following categories: 1) alternatives for treatment or disposal at an offsite facility; 2) alternatives that attain ARARs; 3) alternatives that exceed ARARs; 4) alternatives that do not attain ARARs but that reduce the likelihood of present or future threat from the hazardous substances, and that provide significant protection to public health and welfare and the environment; and 5) a no-action alternative.[7]

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4 Id.

5 CERCLA § 121(d)(1), 42 USC § 9621(d)(1).

6 CERCLA § 121(d)(2)(A) and (d)(4), 42 USC § 9621(d)(d)(A) and (d)(4).

7 40 CFR § 300.68(f)(1).

REMEDIAL ACTION OBJECTIVES

Remedial action objectives are essentially site cleanup goals, designed to address the site problems identified in Chapter 4. Remedial action objectives are expressed in terms of meeting ARARs, when available. When ARARs are not available or not adequately protective, remedial action objectives are expressed in terms of meeting other site-specific human health and environmental protectiveness standards. In general, remedial action objectives should be as specific as possible without unduly limiting the range of alternatives that can be developed.[8]

The remedial action objectives specify the contaminants of concern, the media (e.g., soils, sediments, groundwater, and surface water) of interest, exposure pathways, and acceptable contaminant levels (e.g., ARARs) for each exposure route.[9] Remedial action objectives for protecting human receptors from contaminated media should express both a contaminant level and an exposure route; appropriate protection can be achieved by reducing contaminant levels, reducing exposures, or a combination of these two approaches.[10] In contrast, remedial action objectives for environmental (e.g., plants, wildlife, water) receptors generally seek to preserve a resource and, thus, should be expressed in terms of cleanup levels for the particular media, whenever possible.[11]

Contaminant-specific ARARs, when available and adequately protective, should form the basis of the site

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8 USEPA, 1988. 4-3 and 4-7.

9 Id. 4-7 and 4-15.

10 Id.

11 Id.

objectives.[12] When contaminant-specific ARARs are not available (as for human exposure to contaminated soil at the Warm Springs Ponds Operable Unit), then site-specific human health and environmental protectiveness standards, identified through the public health and environmental assessment process, form the basis of the remedial action objectives.[13] Site-specific human health and environmental protectiveness standards also form the basis of remedial action objectives when contaminant-specific ARARs are not adequately protective (e.g., if multiple contaminants pose a cumulative risk not adequately protected by the ARAR).

Based on the identified problems, the results of the Public Health and Environmental Assessment, and the analysis of ARARs, a list of remedial objectives has been established for the Warm Springs Ponds Operable Unit:

- For pond bottom sediments, the remedial objective is to prevent releases of the pond bottom sediments from design floods or earthquakes (0.5, 0.3, and 0.2 PMF for Ponds 3, 2, and 1, respectively).

- For surface water, the remedial objectives are to:

  - Meet ambient water quality standards established pursuant to the Montana Water Quality Act at a compliance point just above the defined starting point of the Clark Fork River. The precise point at which compliance will be measured will be established by the lead agency in the Record of Decision.

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12 Id. 4-3.

13 Id.

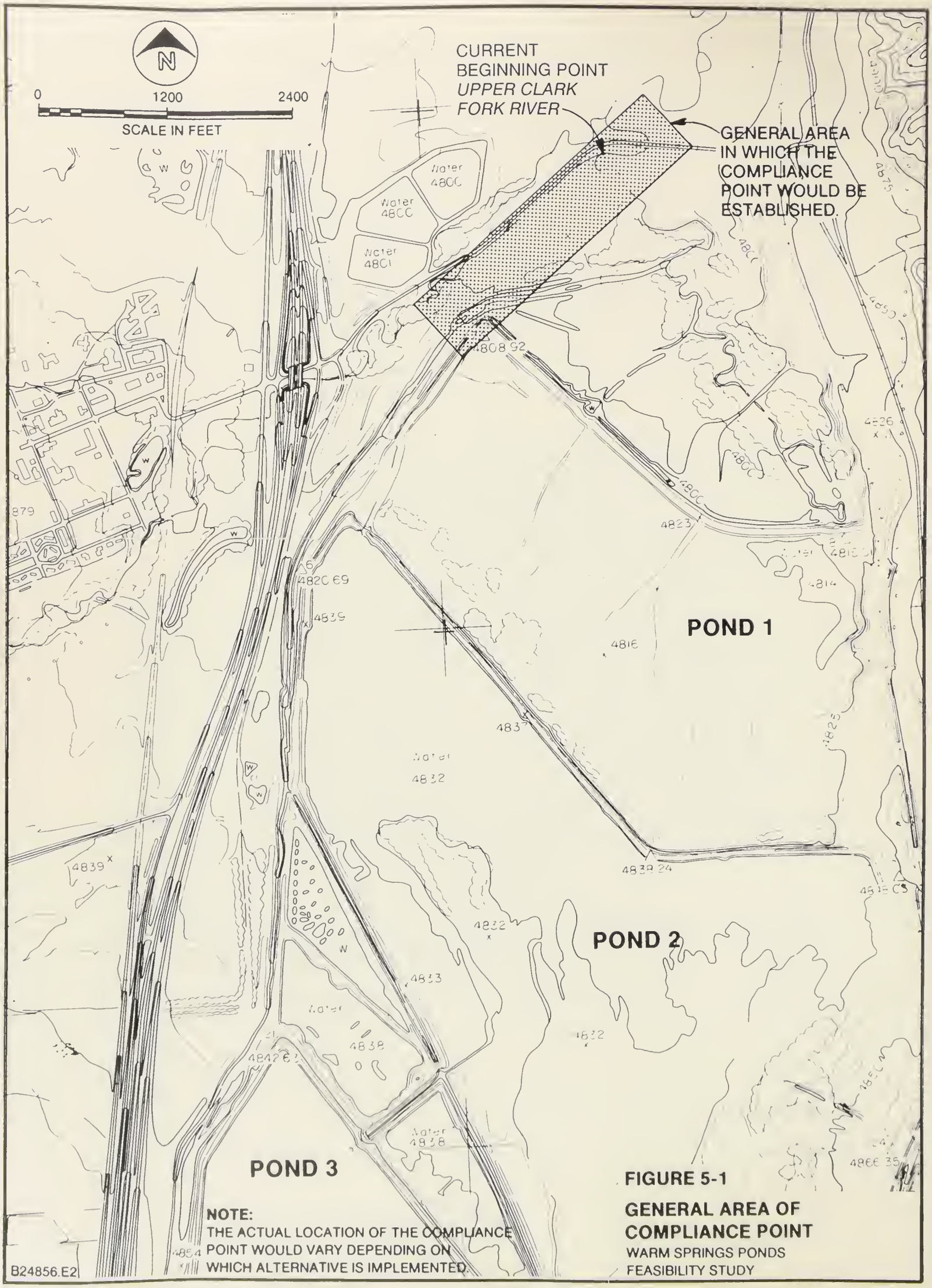

FIGURE 5-1

GENERAL AREA OF COMPLIANCE POINT

WARM SPRINGS PONDS FEASIBILITY STUDY

- Prevent ingestion of water within the operable unit above the Montana Public Water Supply Act's maximum contaminant levels, ambient standards to protect public health, and established reference doses for copper, iron, lead, zinc, and cadmium. Also prevent ingestion of water containing arsenic in concentrations that would cause an excess cancer risk greater than 10^{-4} to 10^{-7}.

- Reduce the migration of tailings from the Mill-Willow Bypass to the Clark Fork River in order to reduce the potential for future exceedances of ambient water quality standards in the Clark Fork River.

- Reduce the migration of tailings from the upper reaches of Silver Bow, Mill, and Willow Creeks to the Clark Fork River in order to reduce the potential for recontamination of the Mill-Willow Bypass and future exceedances of ambient water quality standards in the Clark Fork River.

o For tailings deposits and contaminated soils, the remedial objective is to establish an appropriate vegetative cover capable of self-regeneration and to reduce the potential for human exposure to exposed tailings and other surface contamination (including exposed sediments within the ponds) in order to satisfy acceptable intake criteria for direct contact, ingestion, and inhalation; specifically, reduce the potential for direct contact, inhalation, and ingestion of exposed soils posing excess cancer risks above 10^{-4} to 10^{-7}.

- For groundwater, the remedial objective is to reduce the levels of arsenic and cadmium concentrations in the groundwater in the Pond 1 area to achieve compliance with Montana groundwater maximum contaminant levels.

Table 5-1 shows the relationship between these seven remedial action objectives and the eight problems identified in Chapter 4.

The rationale for these remedial action objectives, for both human health and environmental protection, are described in the following sections.

POND BOTTOM SEDIMENTS

Human Health and Environmental Protection

Because the pond bottom sediments are largely under water, there is no current direct pathway for human exposure to these sediments. However, to prevent future human and environmental exposure to the pond bottom sediments, the release of sediments must be prevented. Such releases could come both from floods and earthquakes and from scouring during other high flow events.

If the pond sediments are left in place in their current unstabilized form, Montana's dam safety rules require a minimum level of protection for the ponds.

SURFACE WATER

Human Health Protection

The remedial action objectives include reducing the potential for ingestion of water containing copper, iron, lead,

Table 5-1
RELATIONSHIP OF SITE PROBLEMS TO REMEDIAL ACTION OBJECTIVES

Problems	Objectives
Pond Bottom Sediments	
Pond integrity--floods. Pond integrity--earthquakes.	Prevent the release of the pond sediments from design floods and earthquakes
Surface Water	
Fishkills	Meet ambient water quality standards for aquatic life at the identified compliance point
Metal loads in the flows of Mill, Willow, and Silver Bow Creeks	Prevent ingestion above maximum contaminant levels and established reference doses for copper, iron, zinc, and cadmium. Also prevent ingestion of water containing arsenic in concentrations that would cause an excess cancer risk greater than 10^{-4} to 10^{-7}
Erosion of tailings in the Mill-Willow Bypass into the Clark Fork River	Reduce the potential for tailings in the Mill-Willow Bypass to reach the Clark Fork River
Transport of tailings from upstream reaches of Silver Bow Creek to the Clark Fork River during floods and other high flow events	Reduce the potential for tailings in upstream areas of Silver Bow Creek to reach the Clark Fork River
Tailings Deposits and Contaminated Soils	
Human and environmental exposure to surface contamination	Reduce the potential for human exposure to exposed tailings and other surface contamination to satisfy acceptable intake criteria
Groundwater	
Contaminated groundwater in the Pond 1 area	Reduce the metals contamination in the groundwater downgradient of the ponds to achieve compliance with maximum contaminant levels

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zinc, and cadmium in excess of the Montana maximum contaminant levels, the ambient standards to protect public health, or established reference doses, and reducing the potential for ingestion of water containing arsenic in concentrations that would result in an excess cancer risk greater than 10^{-4} to 10^{-7}.

Environmental Protection

Meeting the acute and chronic ambient water quality standards established pursuant to the Montana Water Quality Act is the remedial action objective for the protection of aquatic organisms. These standards were established for the protection of all aquatic organisms, including fish, insects, and plants.

The migration of tailings from both the Mill-Willow Bypass and the upper reaches of Silver Bow Creek cause ambient water quality exceedances, including acute and chronic exceedances of copper, zinc, cadmium, and lead. Additionally, tailings migration results in violations of both Montana's nondegradation standard and the proscription against increases above naturally occurring concentrations of sediments that will render waters harmful to aquatic life. Therefore, the remedial action objective for these tailings is to meet surface water ARARs directly after remedy implementation and to minimize the redeposit and migration of tailings in and through the operable unit, thereby preventing future exceedances of the standards and recreation of the same violations caused by onsite tailings deposits today.

This feasibility study selected the 100-year flood as the highest flood for which protection against transport of

upstream tailings would be studied. This selection was made for purposes of the study only, and does not reflect either a regulatory or engineering limit on the level of protection that either could or should be provided.

Protection from the damage caused by floods is often designed on the basis of a 100-year flood, and it is the 100-year flood level that is used in the National Flood Insurance Protection program for determining the insurability of structures. This familiar flood level was chosen partly for its common use in other flood protection studies, and partly because the flood modeling study[14] provides detailed calculations of its hydrograph. Other levels of protection are possible, and may be selected in the final remedy, rather than protection from the 100-year flood.

TAILINGS DEPOSITS AND CONTAMINATED SOILS

Human Health and Environmental Protection

The tailings deposits and contaminated soils present human health hazards for both direct contact and for inhalation and ingestion through the air pathway. The air is not one of the contaminated media for this feasibility study, but it is a pathway for exposure to the tailings deposits and contaminated soils. Remedial actions on the tailings and soils should be in part directed at blocking this pathway and reducing the potential for direct contact. Additionally, the tailings deposits and contaminated soils pose environmental hazards, as evidenced by the absence of vegetation in areas around the operable unit.

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[14] CH2M HILL, 1988. Silver Bow Creek Flood Modeling Study. Prepared for the State of Montana Department of Health and Environmental Sciences, Helena, Montana.

As noted in Chapter 3, there are no applicable or relevant and appropriate requirements for cleaning up the tailings deposits and contaminated soils. For the purpose of this study, health-based target cleanup levels have been selected for use in developing remediation concepts and cost estimates; those levels are 250 ppm arsenic and 750 ppm lead. Actual target cleanup levels will have to be established in the Record of Decision.

GROUNDWATER

Human Health and Environmental Protection

Remedial actions must reduce the potential for ingestion of water having arsenic and cadmium in excess of the Montana groundwater primary maximum contaminated levels. The groundwater must be restored to meet the primary maximum contaminant levels for arsenic and cadmium.

GENERAL RESPONSE ACTIONS

Having identified the remedial action objectives, the next step in developing media-specific actions is to identify the general response actions (cleanup techniques) that will satisfy the remedial action objectives for each of the media of interest.[15] Techniques such as containment, treatment, removal, and institutional controls, to name a few, represent general response actions.

General response actions are media-specific and many may be available and appropriate to address each of the contaminated media at a site. For example, contaminated soil may be excavated and moved to a safer place (removal), secured

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[15] USEPA, 1988. 4-3 and 4-15.

in place (containment), or treated in place to render it less hazardous (in situ treatment). A combination of general response actions, or only one general response action, may be used to provide remedial action for one of the contaminated media.

Table 5-2 identifies the general response actions available to achieve the seven remedial action objectives at Warm Springs Ponds.

INSTITUTIONAL CONTROLS

Institutional controls, like the engineering controls of treatment, containment, and removal, represent one type of general response action. Institutional controls consist of legal mechanisms to prevent or limit access to, or use of, contaminated media, such as groundwater, surface water, or soils, principally to minimize human exposure to the contamination. The discussion that follows is provided in this feasibility study because the function served by institutional controls in a remedial action plan is unlike the function served by engineering technologies.[16]

Institutional controls include both governmentally enacted restrictions to land use, such as zoning ordinances, and owner-imposed restrictions to land use, such as restrictive covenants or easements. Such land use restrictions could include prohibiting residential, commercial, or certain recreational uses of property within boundaries of the Operable Unit or restricting use of surface water until the surface

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[16] A comprehensive presentation of the use of institutional controls under CERCLA is contained in a legal memorandum included in the administrative record for the Warm Springs Ponds Operable Unit.

Table 5-2

GENERAL RESPONSE ACTIONS FOR WARM SPRINGS PONDS

Objectives	Problems	General Response Actions[1]
MEDIA--Pond Bottom Sediments		
1. Prevent the release of pond bottom sediments from design floods and earthquakes	Pond integrity--Floods can cause release of sediments	No action
		Raise the berms to keep them from being overtopped by a flood (Containment)[2]
		Armor the berms against high velocity flows (Containment)
		Construct or enlarge bypass channels (Containment)
		Construct spillways to pass flood flows out of ponds without berm damage (Containment)[3]
		Remove the contents of the ponds from the floodplain (Removal)
		Treat the contents of the ponds after removal to decrease toxicity (Treatment)
		Dispose of sediments, with or without previous treatment (Disposal)
		Solidify pond bottom sediments in place (Chemical Stabilization)
	Pond integrity--Earthquakes can cause release of sediments	No action
		Add rock or other fill material (weight) to the berms (Physical Stabilization)
		Remove the contents of the ponds from the floodplain (Removal)
		Treat the contents of the ponds after removal to decrease toxicity (Treatment)
		Dispose of sediments with or without previous treatment (Disposal)
		Solidify pond bottom sediments to reduce their earthquake susceptibility (Stabilization)

[1] The standard terminology for the general response actions is given in parentheses.

[2] The general response actions listed would upgrade the current containment of the tailings and sediments. Therefore, they are assigned the designation "Containment."

[3] This general response action assumes that the flood would be allowed to flow through the ponds. The preceding three general response actions assume that the flood would be diverted around the ponds.

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Table 5-2 (Continued)

Objectives	Problems	General Response Actions[1]
MEDIA--Surface Water		
2. Meet water quality standards for aquatic life at the identified compliance point	Fishkills	No action Isolate the tailings (the contaminant source) from the streamflow (Containment) Remove contaminants from the streambed (in this case, the Mill-Willow Bypass) (Removal) and treat or dispose of them in an appropriate way (Treatment or Disposal)
	Dissolved metals in the flows of Mill, Willow, and Silver Bow Creeks	No action Treat the streamflow (in this case, improve or replace the current treatment system) (Treatment)
3. Prevent ingestion of water within the operable unit above maximum contaminant levels and above established reference doses for copper, iron, lead, zinc, and cadmium. Also prevent ingestion of water containing arsenic in concentrations that would cause an excess cancer risk greater than 10^{-4} to 10^{-7}.	Dissolved metals in the flows of Mill, Willow, and Silver Bow Creeks	No action Treat the streamflow (in this case, improve or replace the current treatment system) (Treatment)
4. Reduce the potential for tailings in the Mill-Willow Bypass to reach the Clark Fork River	Erosion of tailings in the Mill-Willow Bypass into the Clark Fork River	No action Cap or otherwise stabilize the surface against erosion (Containment) Remove the tailings from the bypass (Removal) and dispose of them in an appropriate way (Disposal) After removal, treat the tailings to reduce their toxicity or mobility. Treatment may be used prior to disposal (Treatment)
5. Reduce the potential for tailings in upstream areas of Silver Bow Creek to recontaminate the Mill-Willow Bypass and reach the Clark Fork River[4]	Floods and other high flow events can cause transport of tailings from upstream reaches of Silver Bow Creek to the Clark Fork River	No action Provide a settling basin to reduce the flow rates and allow for settling (Containment) Filter the streamflow (Treatment)

[4]General response actions that would directly address the upstream tailings, such as removal or stabilization, are not considered in this feasibility study. Such alternatives will be evaluated in a separate feasibility study addressing the upstream areas.

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Table 5-2 (continued)

Objectives	Problems	General Response Actions[1]
MEDIA--Tailings Deposits and Contaminated Soils		
6. Reduce the potential for human exposure to exposed tailings and other surface contamination to satisfy acceptable intake criteria and establish an appropriate vegetative cover capable of self-regeneration.	Human and environmental exposure to surface contamination	No action Remove the surface contamination to reduce its toxicity or mobility (Treatment) Cap or otherwise isolate the surface contamination (Containment) Limit access to the site (Institutional Controls) Fencing (Institutional Controls)
MEDIA--Groundwater		
7. Reduce the metals contamination in the groundwater downgradient of the ponds to achieve compliance with maximum contaminant levels	Contaminated groundwater in the area below the Pond 1 berm	No action Remove contaminant sources causing the groundwater contamination (Removal) Stabilize the contaminant sources causing the groundwater contamination (Treatment) Cap or otherwise isolate the contaminant sources (Containment) Treat the contaminant sources (e.g., sediments in the area and exposed tailings) (Treatment) Pump to remove the contaminated groundwater (Removal) Treat the groundwater after removal (Treatment) Treat the groundwater in place (Treatment) Limit access to the groundwater (Institutional Controls)

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water satisfies applicable or relevant and appropriate health protection standards and requirements. These examples are illustrative, not exclusive.

Institutional controls are not intended to, nor do they result in, cleanup of hazardous substances, pollutants, and contaminants. They, therefore, fail to satisfy Superfund's preference for selection of "remedial actions in which treatment...permanently and significantly reduces the volume, toxicity, or mobility of the hazardous substances, pollutants, and contaminants..."[17] Moreover, while institutional controls assist in the protection of human health by limiting human exposure to hazardous substances, any protection they provide to the environment is both incidental and minimal. Institutional controls, therefore, fall short of Superfund's mandate to "select a remedial action that is protective of...the environment..."[18] except in the most exceptional circumstances, which do not apply here.

Consequently, institutional controls generally should be used as an aspect of site cleanup, if at all: 1) as a temporary protective measure during the implementation of a permanent remedy (e.g., access restriction during excavation); 2) for short-term protection as part of a removal measure (e.g., prohibiting human access to a contaminated area for emergency protection following a spill); or 3) to enhance the effectiveness of a remedial action selected as the appropriate extent of remedy consistent with the National Contingency Plan[19] (e.g., to supplement a remedy consisting of groundwater treatment by prohibiting use of the groundwater for drinking purposes until cleanup is

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17 CERCLA § 121(b)(1), 42 USC § 9621(b)(1).

18 CERCLA § 121(b)(1), 42 USC § 9621(b)(1).

19 CFR § 300.68(i).

attained). Institutional controls should only rarely be used as the sole element of a permanent remedy.[20]

The discussion that follows describes the more general categories of institutional controls available for use at the Warm Springs Ponds Operable Unit. MDHES, with the concurrence of USEPA, has determined that institutional controls may be used at this site to supplement and enhance the overall effectiveness of remedial actions consisting of engineering controls. This discussion evaluates institutional controls in terms of implementability, short- and long-term reliability or effectiveness, and cost. Specific institutional controls, if any, that are suitable for use to enhance the appropriate extent of remedy for the Warm Springs Ponds, will be identified for the remedy selected after public input is received.

ZONING ORDINANCES AS INSTITUTIONAL CONTROLS

Land use planning, generally, and zoning ordinances, specifically, may be used by local governmental authorities to promote compatible and appropriate land use and development, efficient operation of services and utilities, and health, safety, convenience, and welfare of citizens within communities. Consistent with these purposes, zoning regulations limiting access to or use of contaminated media exemplify one type of institutional control available for use at the Warm Springs Ponds.

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[20] Regulations promulgated by USEPA, in effect at the time this feasibility study was conducted (the National Contingency Plan, or "NCP"), make only minimal reference to the use of institutional controls at Superfund sites. 40 CFR §§ 300.6, 300.65(c)(1), and 300.68(j)(1) and (4) (1985). See also USEPA's proposed changes to the NCP, not yet in effect, for a similar view as to the restricted function served by institutional controls in remedy selection. Preamble to Proposed Revisions to NCP, 53 Fed. Reg. 51,423 (1988), amending 40 CFR Part 300.

Montana law provides two methods by which a local governing body may regulate land use within its jurisdiction. The first method entails adoption of a master plan and subsequent adoption of zoning regulations in accordance with the master plan.[21] The second method entails landowner petition to the board of county commissioners for creation of a planning and zoning commission, establishment of development districts, and subsequent adoption of zoning regulations in accordance with the districts.[22]

To adopt zoning regulations under the first method, the local planning board first must propose a master plan, as well as boundaries and regulations for zoning districts to the board of county commissioners of Anaconda-Deer Lodge County.[23] The board of county commissioners possesses ultimate authority to adopt the master plan and zoning regulations in accordance with the plan. Public notice and at least three distinct opportunities for public comment are provided by statute. Adoption of zoning regulations can be prevented by the protest of 40 percent of the landowners within the proposed zoning district.

The second method for adopting zoning regulations within the Warm Springs Ponds Operable Unit requires initiation, through petition, by 60 percent of the affected landowners. A planning and zoning commission, established by the board of county commissioners, can adopt a development plan for a

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21 This method is set forth in its entirety in MCA Title 76, Chapter 1 and Title 76, Chapter 2, Parts 2 and 3.

22 This method is set forth in its entirety in MCA Title 76, Chapter 2, Part 1.

23 The Warm Springs Ponds Operable Unit is located in Deer Lodge County, Montana. Pursuant to Montana law, Deer Lodge County and the City of Anaconda have consolidated their governments into one entity, Anaconda-Deer Lodge County. This discussion assumes enactment and enforcement of zoning regulations at the consolidated governmental level, hereinafter the "City-County."

planning and zoning district consisting of at least 40 contiguous acres. The development district, including zoning and land use regulations, is implemented by the board of county commissioners, by resolution. This approach includes a simplified public notice and hearing requirement.

EASEMENTS AND COVENANTS AS INSTITUTIONAL CONTROLS

Easements and covenants constitute conditions placed on land by the owners of the land. Easements and covenants are the primary methods available for landowners to control land use and, like zoning regulations, can be used as institutional controls to limit or otherwise regulate access to or use of contaminated media.

An easement most commonly entitles the easement holder to use land of another for a specific purpose. A covenant is a promise or agreement between two or more parties to use or not to use land in a particular way.

Easements

Montana statutes define the purposes for which easements may be created.[24] An easement may be affirmative, thereby authorizing the easement holder to take some action on the land of another, such as authorizing a right-of-way for a specified purpose. An easement also can be negative, whereby the owner of the land to which the easement applies is precluded from conducting otherwise lawful activities. An easement may be perpetual, for a specific period of time, or until a stated event or condition occurs. In Montana, any easement properly created and recorded may be transferred and enforced by subsequent holders of the easement,

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[24] MCA §§ 70-17-101 and -102.

so long as the grant creating the easement did not limit its transferability. This attribute of transferability, and the concomitant right of enforcement, are essential if easements are to possess any long-term effectiveness as aspects of remedial action.

Covenants

Covenants, or promises to do or refrain from doing some action with respect to land have much in common with easements. Typically, however, the activities about which parties covenant are broader in scope than the activities covered by easements.[25] For example, covenants commonly include promises to use land only for residential or single family dwellings or promises to pay an annual fee for maintenance of common property, such as lawns, walkways, or parks.

As with easements, to remain enforceable, covenants should be contained in a written grant and be properly recorded in the office of the county clerk and recorder. If not properly recorded, a subsequent property transfer may vitiate the covenant. Covenants may be terminated by expiration of the original term agreed to by the parties; ownership of the "burdened" land by the same person holding the "benefited" land; abandonment; release; changed conditions; and similar events.

EVALUATION OF PUBLIC AND PRIVATE LAND USE RESTRICTIONS

When specific institutional controls are identified to enhance an engineering technology for the site cleanup, they will require specific evaluation, just as other technologies

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[25] Natelson, Montana Running Covenants: Statutory Itent and Modern Reality 24, 28, 32, and 39-40 (unpublished article, presented on April 7, 1989; available from University of Montana School of Law).

require evaluation, on the basis of their implementability, effectiveness, and cost.[26] The following discussion presents some general comments that can be made about these broad categories of institutional controls concerning their implementability, effectiveness, and cost.

Serious implementability concerns exist with respect to enacting zoning regulations as a supplement to remedial action at the Warm Springs Ponds Operable Unit. Such regulations will be enacted only at the will of local governmental officials in Anaconda-Deer Lodge County. Support (and, under the second method for enacting zoning regulations, the initiative) of landowners within the Operable Unit also is necessary.

In contrast, the use of easements or covenants as institutional controls presents fewer implementability concerns. Land use restrictions may be incorporated in a deed to real property owned by a party liable under Superfund either through negotiation or through judicial enforcement of remedial actions under Superfund.

Zoning regulations, covenants, and easements all pose reliability concerns. Even if Anaconda-Deer Lodge County enacted zoning regulations, their future repeal or relaxation cannot be prevented. Likewise, local governmental enforcement, now and in the future, cannot be guaranteed, as enforcement involves policy and resource questions outside the ambit of Superfund. Complex legal requirements must be met to ensure the enforceability of covenants and easements. As with zoning regulations, there is no guarantee that the holder of an easement or a covenant will exercise its enforcement power should this need arise in the future.

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[26] 40 CFR § 300.68(g) (1985). The evaluation for other technologies considered in this feasibility study occurs in Chapter 6.

The cost of implementing and monitoring an institutional control will vary widely depending on the control. The cost of an institutional control includes the cost of implementation, operation and maintenance, and reduction in property value attributed to the land use restriction.

Notwithstanding these real difficulties concerning the implementation and reliability of governmental or landowner imposed land use restrictions under Superfund, institutional controls may enhance the effectiveness of an engineering system selected as the appropriate extent of remedy for site remediation consistent with federal regulations. Accordingly, when a remedy is selected it will be possible to more specifically elaborate on the ability of specific institutional controls to enhance the remedy.

AREAS AND VOLUMES OF CONTAMINATED MEDIA

Table 5-3 shows the total areas and volumes of contaminated media to which the general response actions may be applied for each of the media. In quantifying the areas and volumes of contamination to which the general response actions may be applied, this study considered the chemical and physical characteristics of the site, including potential exposure routes and the levels of protectiveness specified in the remedial action objectives.[27] Actual areas and volumes remediated will depend on the target cleanup levels established in the Record of Decision, and may be smaller than the estimates of total areas and volumes listed in Table 5-3.

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[27] USEPA, 1988. 4-3 and 4-15.

Table 5-3
SUMMARY OF AREAS AND VOLUMES OF MEDIA

	Area (acres)	Volume (acre-feet)	Volume (cubic yards)
Media 1--Pond Bottom Sediments			
Pond 1			
Exposed Sediments	59	455	734,000
Vegetated/Submerged Sediments	225	1,340	2,156,000
	284	1,795	2,890,000
Pond 2			
Exposed Sediments	155	800	1,300,000
Vegetated/Submerged Sediments	347	2,230	3,590,000
	502	3,030	4,890,000
Pond 3			
Submerged Sediments	665	6,930	11,180,000
Total Pond Bottom Sediments	1,451	11,755	18,960,000
Media 2--Surface Water			
Silver Bow Creek[a]			
Mill and Willow Creeks[b]			
Media 3--Tailings Deposits and Contaminated Soil			
Mill-Willow Bypass			
Exposed Tailings	21	47	75,800
Vegetated Tailings and Contaminated Soil	33	80	130,000
	54	127	205,800
Area Above Pond 3			
Exposed Tailings	22	56	90,300
Vegetated Tailings and Contaminated Soil	268	700	1,130,000
	290	756	1,220,300
Area Below Pond 1			
Exposed Tailings	17	48	77,400
Vegetated Tailings and Contaminated Soil	59	246	397,000
	76	294	474,400
Total Tailings Deposits and Contaminated Soil	420	1,177	1,900,500
Media 4--Groundwater[c]			
Area of contaminated aquifer beneath and downgradient of Pond 1	180		

[a]Flow ranges from 28-112 cfs (73 cfs average). Data collected from March 1985 to August 1985.
[b]Flow ranges from 3-87 cfs (27 cfs average). Data collected from December 1984 to August 1985.
[c]Exceedances of primary maximum contaminant levels for arsenic and cadmium.

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Chapter 6
IDENTIFYING A RANGE OF MEDIA-SPECIFIC ACTIONS

In the previous chapter, the first three steps in identifying alternatives for the entire Warm Springs Ponds Operable Unit were performed: 1) identify remedial action objectives, 2) identify general response actions, and 3) identify the areas and volumes of contaminated media to which the response actions may be applied. In this chapter, the next three steps in the alternatives identification process are performed: 4) identify and screen technologies and process options to implement remedial actions, 5) select representative process options, and 6) assemble the selected process options into media-specific actions. The media-specific actions will be further developed in Chapter 7 and assembled in Chapter 8 into remedial alternatives for the entire operable unit.

ALTERNATIVES IDENTIFICATION PROCESS

In this section remedial technologies and process options are screened, representative process options are selected, and media-specific actions are assembled.

REMEDIAL TECHNOLOGIES AND PROCESS OPTIONS

The building blocks for conducting site cleanup are the remedial technologies and process options. Remedial technologies are methods for handling specific technical problems, and include such methods as chemical treatment, capping, dewatering, and excavation. Remedial technologies are more specific than the general response actions (e.g.,

containment, treatment, and removal) described in Chapter 5. In turn, process options are more specific than remedial technologies and describe various processes within a particular remedial technology; for example, capping (a remedial technology) could be done by using a native soil cap or a clay cap (process options).

This study identified an extensive list of remedial technologies and process options applicable to each general response action. Table C-1 in Appendix C contains a list of more than 200 technologies and process options usable at hazardous waste sites. Additionally, because of the special need at the Warm Springs Ponds Operable Unit to protect and stabilize the pond system against floods and earthquakes, Table C-1 includes remedial technologies and process options to address those site objectives.

The technologies and process options were initially screened to eliminate those that are unrelated to the problems at the site or that are technically infeasible for use at the site.[1] For example, the process options of steam stripping and incineration of contaminated soil, listed in Table C-1, are not appropriate at the Warm Springs Ponds Operable Unit because those process options are for treatment of organic contaminants, and the media of concern at this operable unit contain inorganic (metal) contaminants. Similarly, although the more than 20 million cubic yards of wastes at the operable unit could, in principle, be placed in drums for offsite transport, that approach would take so long and involve so many inherent dangers that it was screened out based on its technical infeasibility. Many

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[1] USEPA, 1988. Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA, (Interim Final, October 1988). 4-3 and 4-15 to 4-16.

other technologies and process options were screened out for similar reasons. Table C-1 notes which remedial technologies and process options were screened out at this preliminary stage and provides screening comments explaining their elimination. Table 6-1 lists the technologies and process options retained after the initial screening.

The feasibility study next included a second evaluation and screening of process options for each remedial technology retained in the initial screening.[2] In screening technologies and process options at this stage of the feasibility study, three criteria were used, the most important of which is the effectiveness of the process option at protecting public health and welfare and the environment. To a less significant degree, the process options were screened on the basis of their implementability and cost.[3] Implementability of the process options was evaluated by considering 1) their feasibility given the characteristics of the site and wastes, 2) their applicability to the site problems, 3) their reliability for addressing the problem, and 4) their vulnerability to administrative impediments.[4] At this stage, the implementability evaluation focused more on administrative than on engineering concerns.[5] Cost played a limited role in the screening of process options.[6] Table 6-2 provides screening comments describing

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2 Id. 4-16.

3 Id.

4 See 40 CFR 300.68(g)(2) USEPA, 1988. 4-20.

5 USEPA, 1988. 4-20.

6 Id.

why process options were screened out at this stage. The table is arranged by media. If all of the process options for a given technology were screened out, the technology was likewise screened out in Table 6-2.

SELECTING REPRESENTATIVE PROCESS OPTIONS

Once the process options were screened on the basis of effectiveness, implementability, and cost, one or more process options were chosen to be representative of all the remaining process options for each remaining technology. The process options selected for each technology are intended to be representative of the range of remaining process options for that technology. If two or more process options differ significantly in their performance or effect such that one would not adequately represent the other, more than one process option for a remedial technology was retained.[7] The use of a representative process option, where feasible, simplifies the number of alternatives developed and evaluated in Chapters 7 and 8. This streamlining ensures that the most promising alternatives will be considered fully without wasting resources on details unnecessary at this stage of the alternatives analysis.[8] Selection of a process option at this stage does not preclude use of a different option later, such as during remedial design. Table 6-3 shows which process options were selected to be representative of the remaining process options within each technology.[9] The last section of this chapter provides further

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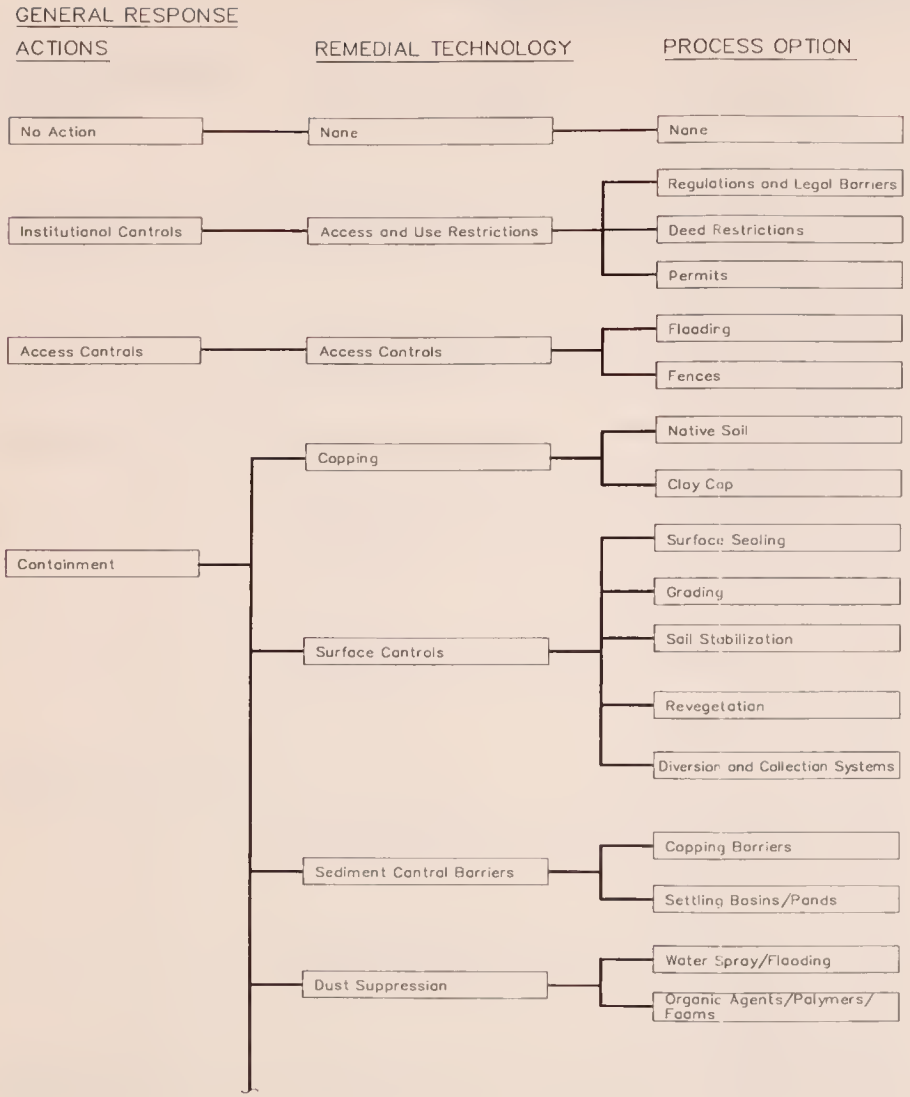
7 USEPA, 1988. 4-16.

8 Id.

9 Note: The USEPA RI/FS Guidance (1988) document does not specify criteria for selecting representative process options. The selection was made on the basis of engineering judgement of which process option would most likely be selected at the design stage of the remedial process. (see Id.)

TABLE 6-1
SUMMARY OF APPLICABLE REMEDIAL TECHNOLOGIES AND PROCESS OPTIONS FOR TREATING SPECIFIC MEDIA

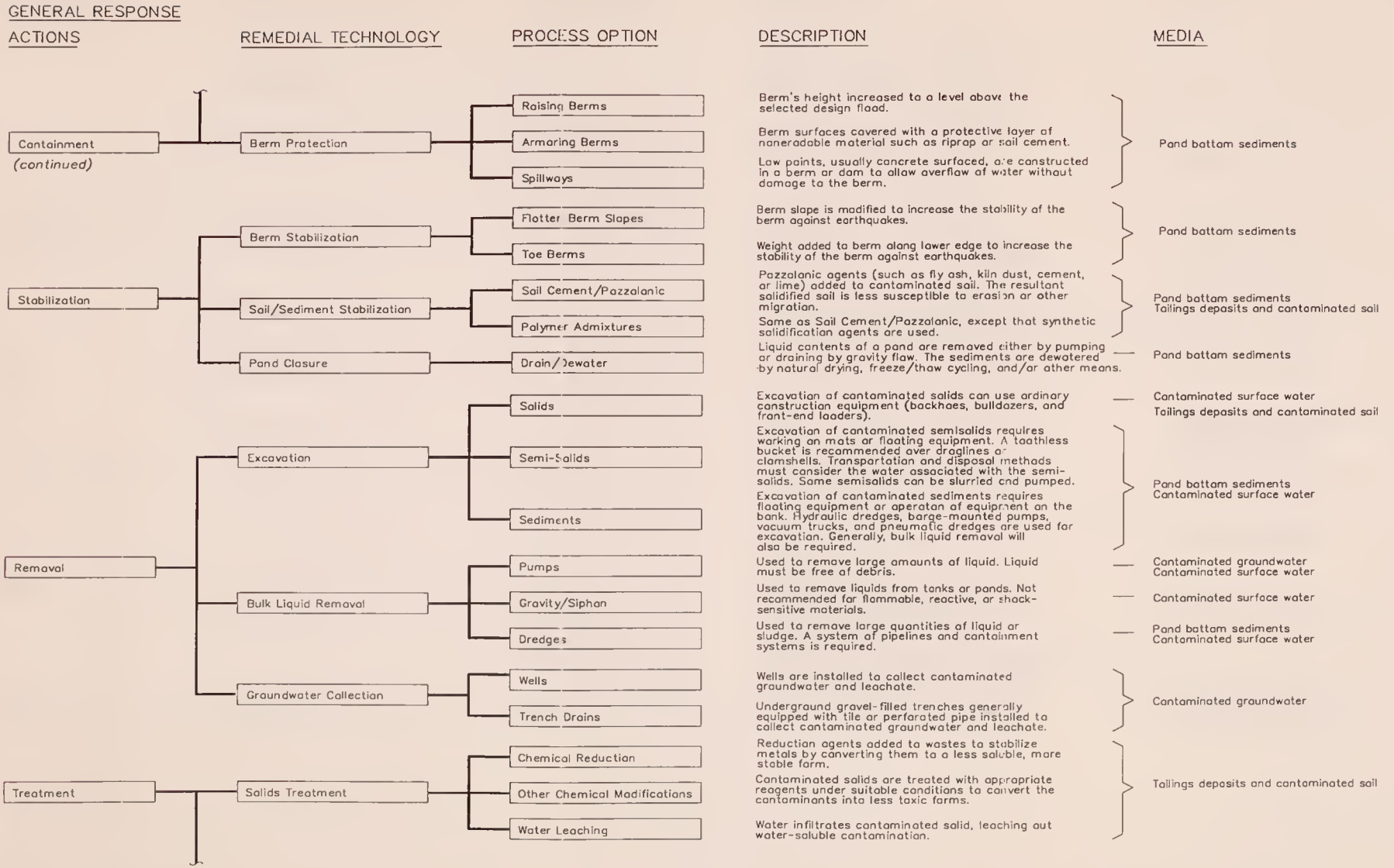


DESCRIPTION	MEDIA
No action	Pond bottom sediments Tailings deposits and contaminated soil Contaminated groundwater Contaminated surface water
No trespassing and other restrictions to limit access and use. May enhance other general response actions.	Tailings deposits and contaminated soil Contaminated surface water
Deed restrictions issued for property within potentially contaminated areas to restrict property use. May enhance other general response actions. Regulations promulgated to prohibit aquifer use or require a permit for drilling into aquifers. May enhance other general response actions.	Pond bottom sediments Tailings deposits and contaminated soil Contaminated groundwater Contaminated surface water
An area is flooded with shallow water to discourage trespassing. (Similar to constructing a wetland)	Tailings deposits and contaminated soil
Security fences installed around potentially contaminated areas to limit access.	Pond bottom sediments Tailings deposits and contaminated soil Contaminated surface water
Uncontaminated native soil placed over contaminated areas. Soil should minimize infiltration of precipitation. Compacted clay placed over contaminated areas. Clay should be covered by a layer of silty sand or sandy soil to maintain the integrity of the clay cap.	Tailings deposits and contaminated soil
Cover materials and seal techniques implemented to stabilize waste deposits and to prevent surface water infiltration, control erosion, and isolate and contain the wastes. Similar to capping. Reshaping of topography to manage surface water, infiltration and runoff to control erosion. Chemical stabilizers sprayed on bare soils or mulches to coat, penetrate, and bind together the particles. Chemical stabilizers include latex emulsions, plastic films, oil-in-water emulsions, and resin-in-water emulsions. A systematic revegetation plan includes selection of a suitable plant species, seedbed preparation, seeding/planting, mulching and/or chemical stabilization, fertilization, and maintenance.	Tailings deposits and contaminated soil
Diversion and collection structures installed upslope or at perimeter of the site to control drainage of stormwater runoff. System can also be implemented to collect contaminated surface water for remediation.	Contaminated surface water
A permeable cap is installed without dewatering when goal is to prevent the spread of contaminated sediments. An impervious cap is installed after dewatering so remediation can be done in a controlled environment. An impoundment is constructed to establish a low flow rate area in either a stream or a runoff flow. The decreased flow rate allows entrained solids to settle out.	Contaminated surface water
Water sprayed over area to prevent dust generation, or flooding of an area to prevent dust generation. Organic agents/polymers/foams sprayed over area of concern to prevent dust generation.	Tailings deposits and contaminated soil

J:\INDUST\B0124856\FIG5-3-1.DWG

TABLE 6-1 (continued)

SUMMARY OF APPLICABLE REMEDIAL TECHNOLOGIES AND PROCESS OPTIONS FOR TREATING SPECIFIC MEDIA



J:\INDUST\B0124856\FIG5-3-4.DWG

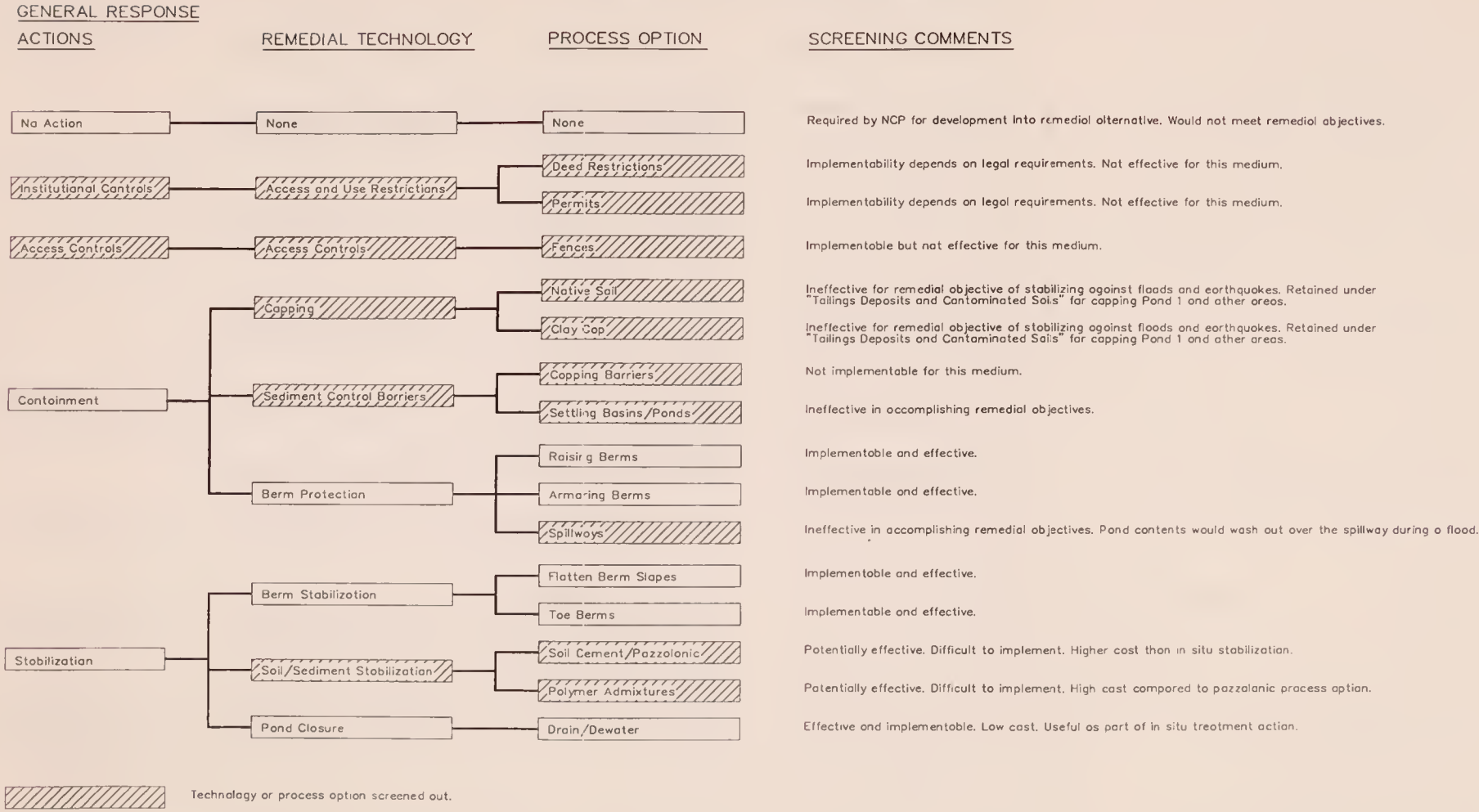
TABLE 6-1 (continued)

SUMMARY OF APPLICABLE REMEDIAL TECHNOLOGIES AND PROCESS OPTIONS FOR TREATING SPECIFIC MEDIA

GENERAL RESPONSE ACTIONS	REMEDIAL TECHNOLOGY	PROCESS OPTION	DESCRIPTION	MEDIA
Treatment (continued)	Solidification, Fixation, Stabilization	Sorption	An inert, nondegradable, nonreactive sorbent added to liquid or sludge to soak up moisture and produce a soil-like material.	Pond bottom sediments
		Pozzolanic Agents	Lime and fine-grained siliceous material added to aqueous waste to produce a concrete-like solid.	
	Solids Dewatering	Freeze/Thaw Cycling	Some hydroxide sludges that are difficult to dewater are more easily dewatered if frozen and then thawed one or more times.	Pond bottom sediments Tailings deposits and contaminated soil
		Dewatering and Drying Beds	Sludge placed on sand layered over gravel. Water in the sludge evaporates and drains.	
	Physical Treatment	Flow and Strength Equalization	Equalization basin regulates flow through a treatment facility. Mechanical mixing equalizes concentration.	Contaminated surface water
		Sedimentation	Suspended solids removed from liquid by gravity in a tank or lagoon. Sedimentation often preceded by chemical precipitation and/or by coagulation and flocculation.	Contaminated groundwater Contaminated surface water
	Chemical Treatment	Precipitation	Chemical equilibria of waste altered to reduce the solubility of heavy metals through the addition of a substance that reacts with the metals or changes the pH or through a change in temperature.	Contaminated groundwater Contaminated surface water
	Biological Treatment	Wetland Treatment	Metals-contaminated water is treated by biological and chemical/physical processes in a wetland.	Contaminated groundwater Contaminated surface water
		Pond Treatment (metals)	Metals-contaminated water is treated by biological and chemical/physical processes in a pond.	
	Resource Recovery	Chemical Reduction	Reduction agents added to wastes for reduction of hexavalent chromium, mercury, dissolved lead, and silver to less soluble, more stable forms.	Pond bottom sediments Tailings deposits and contaminated soil Contaminated groundwater Contaminated surface water
In Situ Treatment	Solids Treatment	Neutralization	Substances applied or injected into a contaminated site to adjust the pH of the waste. Innovative process option for contaminated soils or buried wastes.	Pond bottom sediments Tailings deposits and contaminated soil
		Pozzolanic Agents	Lime and fine-grained siliceous material added to aqueous waste to produce a concrete-like solid.	Pond bottom sediments
Disposal	Wastewater Discharge	Surface Waters	Aqueous streams are discharged to surface receiving streams.	Contaminated groundwater Contaminated surface water
	Land Disposal	RCRA Landfill	Solid hazardous wastes are permanently disposed of in a RCRA-permitted landfill. RCRA landfills cannot accept liquid hazardous waste.	Tailings deposits and contaminated soil Pond bottom sediments Contaminated surface water
		Non-RCRA Landfill	Solid nonhazardous wastes are permanently disposed of in a non-RCRA landfill. Landfills cannot accept liquid wastes.	
		Surface Impoundments	Surface impoundments are used to store ,dispose, or treat liquid and sludge-type waste. Also known as ponds, lagoons, liquid trenches, evaporation ponds, treatment ponds, aeration pits, and stabilization basins.	
Monitoring	Monitoring	Monitoring	Short-and/or long-term monitoring is implemented to record site conditions and contamination levels.	Pond bottom sediments Tailings deposits and contaminated soil Contaminated groundwater Contaminated surface water

J:\INDUST\BDI24856\FIG5-3-8.DWG

TABLE 6-2
REMEDIAL TECHNOLOGY AND PROCESS OPTION SCREENING FOR EFFECTIVENESS, IMPLEMENTABILITY AND COST
POND BOTTOM SEDIMENTS

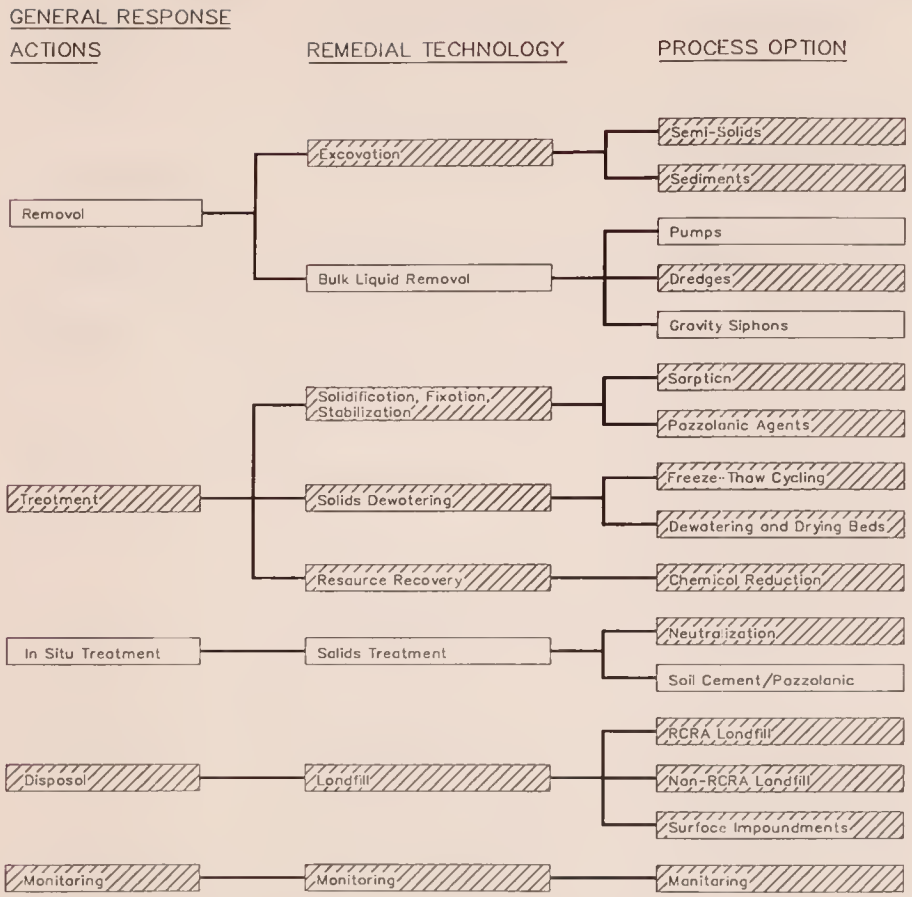


J. \INDUST\80124856\FIG6-2-1.DWG

TABLE 6-2 (continued)

REMEDIAL TECHNOLOGY AND PROCESS OPTION SCREENING FOR EFFECTIVENESS, IMPLEMENTABILITY AND COST

POND BOTTOM SEDIMENTS



SCREENING COMMENTS
Potentially effective. Very difficult and slow to implement. Requires alternative disposal site. Very high cost.
Potentially effective. Very difficult and slow to implement. Requires alternative disposal site. Very high cost.
Effective, implementable, but higher cost than gravity siphons. May be needed for some actions.
Potentially effective, difficult to implement. Higher cost than gravity siphons.
Effective, implementable, and low cost. Useful as part of remedial action.
Not effective in meeting remedial objectives. Would not stabilize sediments against floods or earthquakes. Would increase waste volume.
Potentially effective, difficult to implement. Higher cost than in situ treatment.
Questionable effectiveness. Seasonal implementability. Slow. Low cost.
Ineffective. Would take several decades. Implementation requires excessive time.
Not implementable. Concentrations in soils too low for effective recovery. Recovery operation may present greater hazards than the soils do now. High cost.
Difficult to implement, requires handling hazardous materials. Questionable long-term effectiveness..
Potentially effective. Very difficult implementation. Very high cost.
Difficult to implement. Volume too large. RCRA landfill not available nearby.
Difficult to implement. Requires developing a disposal site.
Difficult to implement. Wastes are already in surface impoundments
Difficult to implement. Questionable effectiveness. Not clear what the sediments would be monitored for.

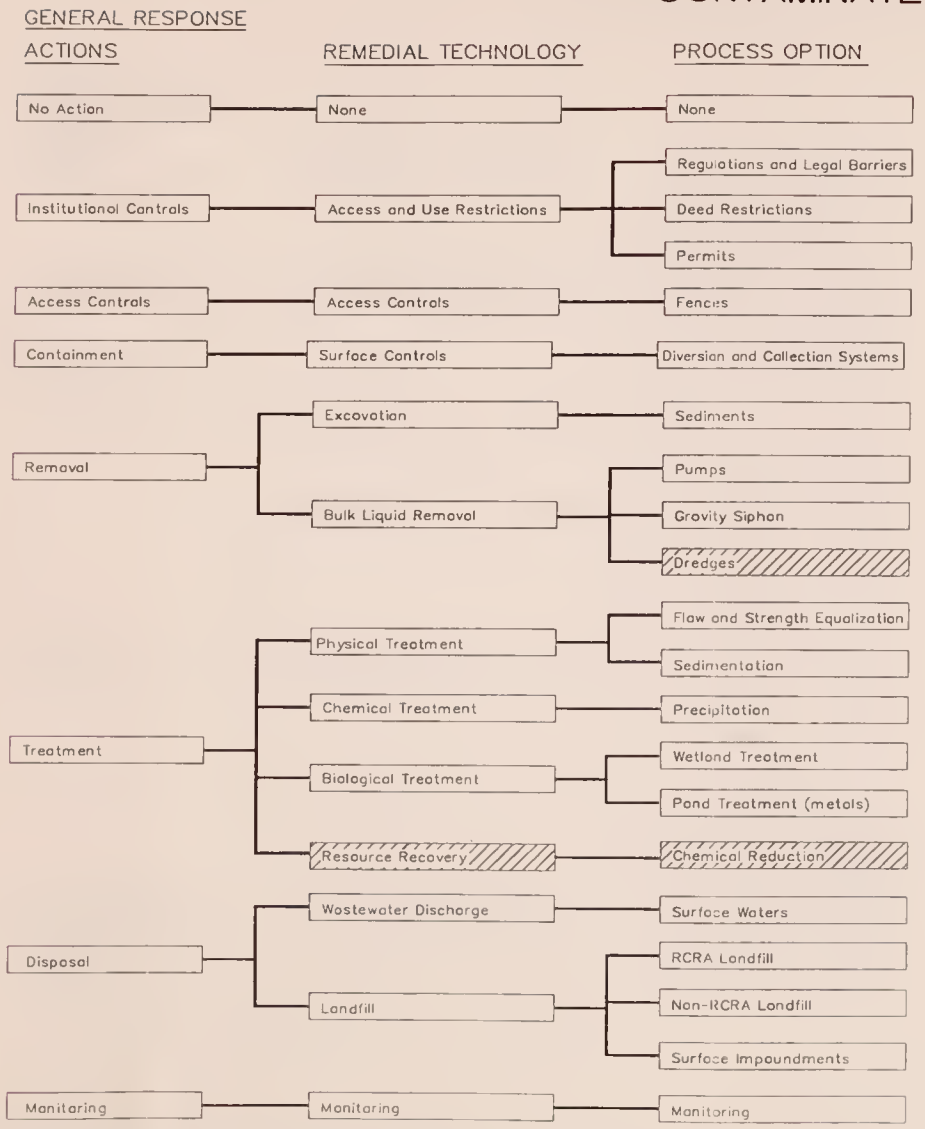
Technology or process option screened out.

J:\INDUST\B0124856\FIG6-2-2.DWG

TABLE 6-2 (continued)

REMEDIAL TECHNOLOGY AND PROCESS OPTION SCREENING FOR EFFECTIVENESS, IMPLEMENTABILITY AND COST

CONTAMINATED SURFACE WATER



SCREENING COMMENTS
Required by NCP for development into remedial alternative. Would not meet remedial objectives.
Implementability depends on legal requirements. Potentially effective to limit human exposure, but not protective of the environment.
Implementability depends on legal requirements. Potentially effective to limit human exposure, but not protective of the environment.
Implementability depends on legal requirements.
Implementable but questionable effectiveness for intended purpose. High cost compared to institutional controls.
Effective and implementable. Moderate cost. Useful as part of a media-specific-action.
(Excavation of sediments causing contamination) Potentially effective and readily implementable.
Potentially effective for removing contaminated surface water. Readily implementable. Relatively costly.
Useful as part of a remedial action.
Not effective or implementable for this medium.
Difficult to implement. Requires development of new impoundment to handle high flows.
Potentially effective, readily implemented if new impoundment is built. Part of current treatment process.
Implementable and potentially effective. Part of current treatment process.
Potentially effective but implementability uncertain. Requires large area.
Implementable and potentially effective. Part of current treatment process.
Not implementable. Concentrations in surface water too low for resource recovery to be feasible.
Potentially effective and implementable. Low cost. Depends on contamination levels of discharge. Part of current treatment process.
(Disposal of sediments causing contamination) Potentially effective. Readily implementable. Regulatory matters determine use of RCRA vs non-RCRA landfill. Would be used for disposal of sources of surface water contaminants
(Disposal of sediments causing contamination) Not as protective (effective) as RCRA landfill. Would require development of a new disposal site. Regulatory matters determine use of RCRA vs non-RCRA landfill.
(Disposal of sediments causing contamination) Effective and implementable. Low cost. Pond system already contains 19 million yd ^{3} of similar materials. Regulatory matters determine acceptability
Effective and implementable. Moderate cost. Required as part of remedial action.

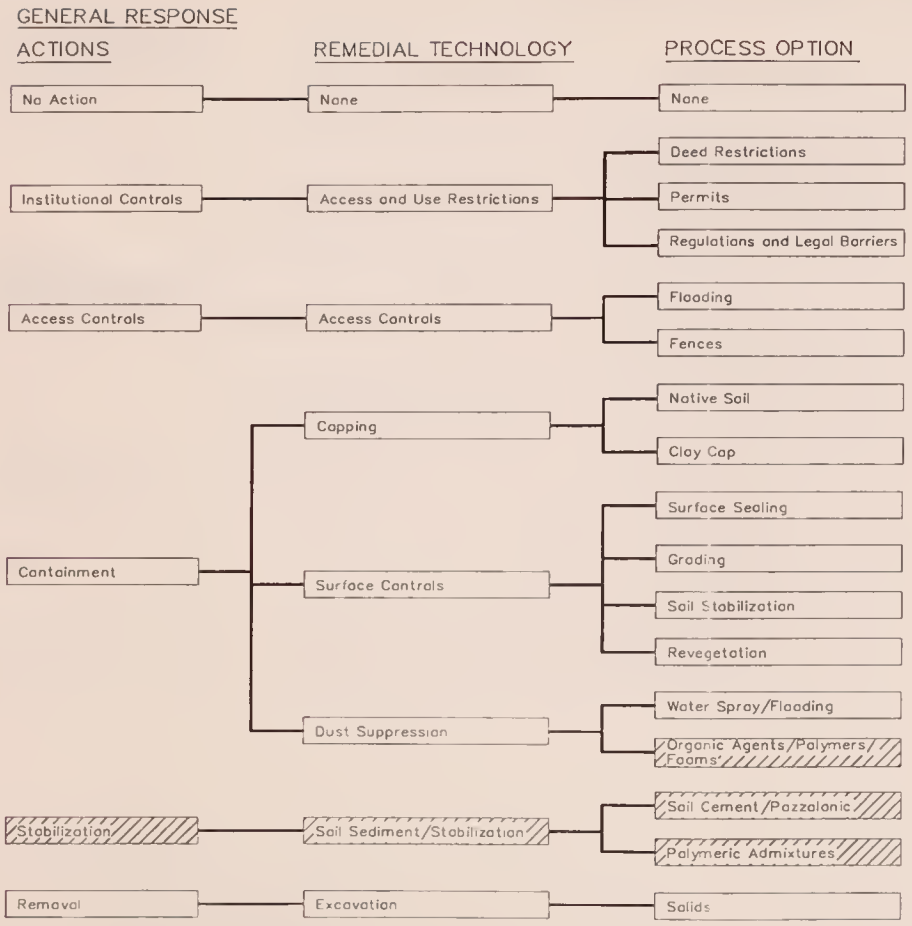
J. \INDUST\BOI24856\FIG6-2-3.DWG

Technology or process option screened out

TABLE 6-2 (continued)

REMEDIAL TECHNOLOGY AND PROCESS OPTION SCREENING FOR EFFECTIVENESS, IMPLEMENTABILITY AND COST

TAILINGS DEPOSITS AND CONTAMINATED SOIL



SCREENING COMMENTS
Required by NCP for development into remedial alternative. Would not meet remedial objectives.
Implementability depends on legal requirements. Not effective for most exposure scenarios and not protective for environment. Could be used to restrict development within operable unit, and enhance other general response actions.
Implementability depends on legal requirements. Not effective for most exposure scenarios and not protective for environment. Could be used to restrict development within operable unit, and enhance other general response actions.
Implementability depends on legal requirements. Potentially effective for reducing human exposure for some scenarios but not protective for environment. Could be used to enhance other general response actions.
Potentially effective for some areas of the site. Implementable.
Implementable. Potentially effective for reducing exposure for some scenarios. High cost due to large areas.
Implementable and effective for some areas of site. Moderate cost.
Implementable and effective. Higher cost than native soil cap due to availability of clay.
See "capping"
Implementable, but questionable effectiveness at achieving remedial objectives if used alone. Useful as a part of some actions.
Implementable and potentially effective Temporary. Could be used instead of capping In some areas of the site, might be damaged by floods.
Potentially effective and implementable. Could be used instead of capping.
Potentially effective for some areas of the site. Readily implemented. Low cost.
Potentially effective, difficult to implement. Higher cost than water spray dust suppression
Potentially effective but difficult to implement. Could be used instead of capping. Higher cost. Loss of habitat.
Potentially effective but difficult to implement. High cost compared to pozzalonic.
Implementable and effective. Addresses fish kill problem and removal of tailings deposits and contaminated soils.

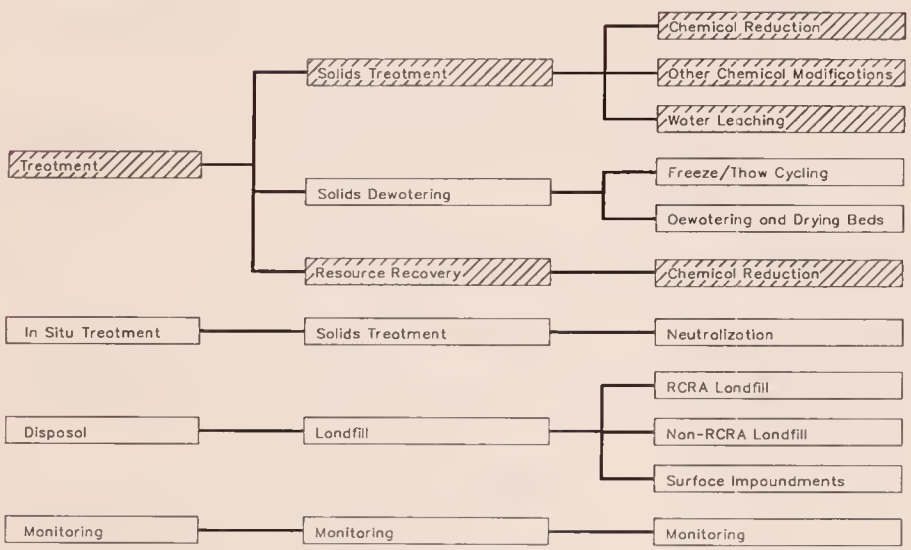
J \INDUST\B0124856\FIG6-2-4.DWG

Technology or process option screened out

TABLE 6-2 (continued)

REMEDIAL TECHNOLOGY AND PROCESS OPTION SCREENING FOR EFFECTIVENESS, IMPLEMENTABILITY AND COST

TAILINGS DEPOSITS AND CONTAMINATED SOIL



SCREENING COMMENTS
Questionable effectiveness. Difficult implementation. Requires handling hazardous materials. High cost.
None identified that would be implementable and effective.
Poor effectiveness, difficult implementability. Metals not sufficiently soluble in water. Slow process.
Natural freeze/thaw cycle may aid drying in drying beds.
Implementable. May be required for some wastes prior to land disposal.
Not implementable. Concentrations in soils too low for effective recovery. Recovery operation may present greater hazards than the soils do now. High cost.
Potentially useful as part of capping action. Reduces mobility of metal contaminants.
Potentially effective. Readily implementable High cost. Regulatory matters determine use of RCRA vs non-RCRA landfill.
Not as protective (effective) as RCRA landfill. Readily implementable, less costly. Regulatory matters determine use of RCRA vs non-RCRA landfill.
Potentially effective and implementable. Low cost. May not be acceptable without treatment of wastes.
Potentially valuable for some general response actions. Required as part of remedial action.

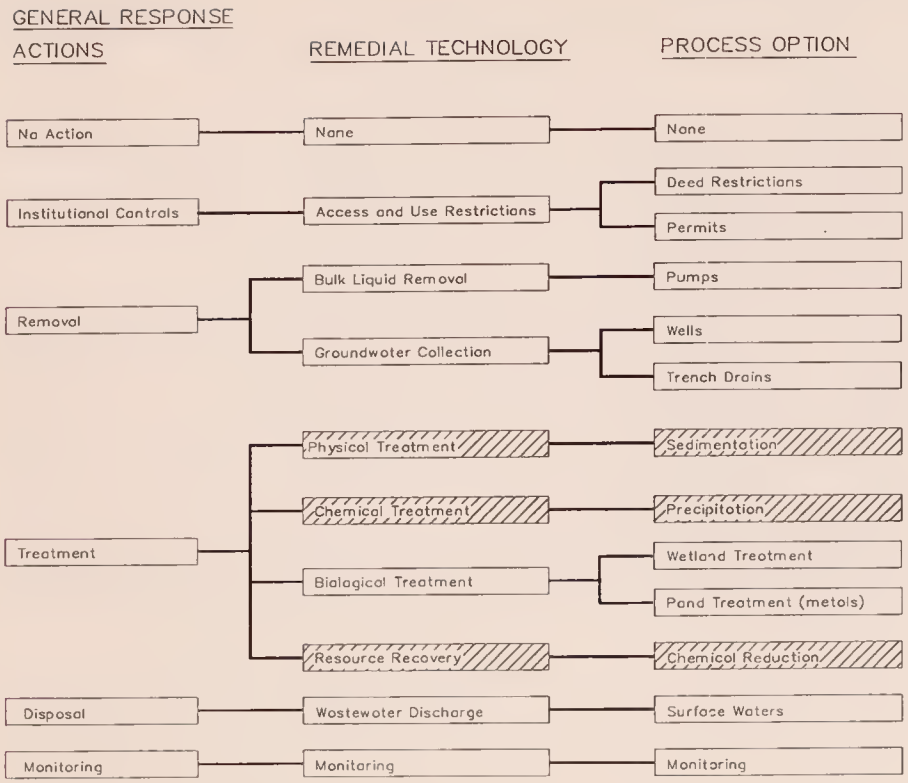
Technology or process option screened out.

J:\INDUST\BOI24856\FIG6-2-5.DWG

TABLE 6-2 (continued)

REMEDIAL TECHNOLOGY AND PROCESS OPTION SCREENING FOR EFFECTIVENESS, IMPLEMENTABILITY AND COST

CONTAMINATED GROUNDWATER

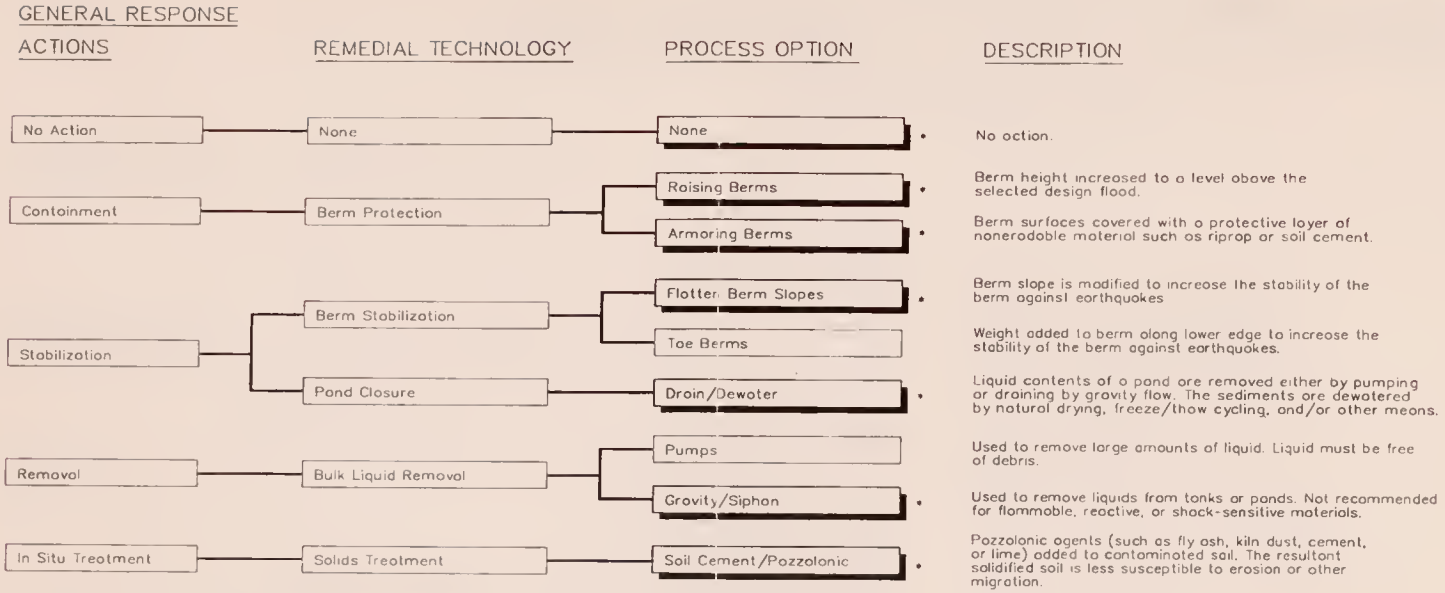


SCREENING COMMENTS
Required by NCP for development into remedial alternative. Would not meet remedial objectives.
Implementable and effective for restricting human exposure, but not for protecting the environment.
Implementable and effective for restricting human exposure, but not for protecting the environment.
Effective for removing contaminated groundwater and transporting it for treatment.
Implementable but less effective and more costly than trench drains. Would require numerous wells.
Effective for removing contaminated groundwater. Readily implementable.
Not required. Groundwater not expected to have suspended solids requiring removal.
Not effective as a pure chemical treatment process: contaminants difficult to remove at low concentrations.
Potentially effective. Implementability difficult. Requires large area. Innovative process option.
Implementable, and potentially effective. Requires pump stations and piping system.
Not implementable. Concentrations in groundwater too low for resource recovery to be feasible.
Potentially effective and implementable. Low cost.
Effective and implementable. Moderate cost. Required as part of remedial action.

Technology or process option screened out.

J. \INDUST\B0124856\FIG6-2-6.DWG

TABLE 6-3
PROCESS OPTIONS RETAINED FOR CONSIDERATION IN THE DEVELOPMENT OF MEDIA-SPECIFIC ACTIONS FOR POND BOTTOM SEDIMENTS



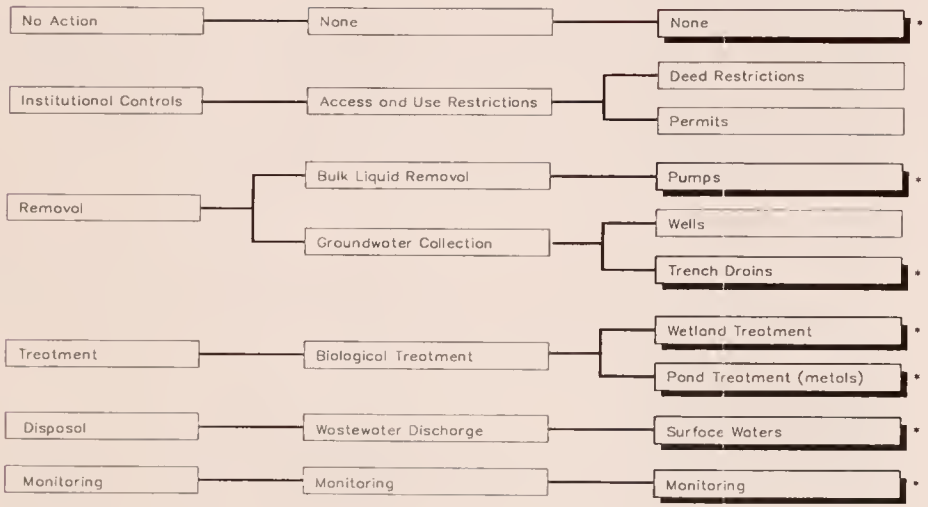
DESCRIPTION
No action.
Berm height increased to a level above the selected design flood.
Berm surfaces covered with a protective layer of nonerodable material such as riprap or soil cement.
Berm slope is modified to increase the stability of the berm against earthquakes
Weight added to berm along lower edge to increase the stability of the berm against earthquakes.
Liquid contents of a pond are removed either by pumping or draining by gravity flow. The sediments are dewatered by natural drying, freeze/thaw cycling, and/or other means.
Used to remove large amounts of liquid. Liquid must be free of debris.
Used to remove liquids from tanks or ponds. Not recommended for flammable, reactive, or shock-sensitive materials.
Pozzolonic agents (such as fly ash, kiln dust, cement, or lime) added to contaminated soil. The resultant solidified soil is less susceptible to erosion or other migration.

• Selected for use in assembling media specific actions. Other process options may later be determined to be more appropriate for use during design or implementation of the remedy.

J:\INDUST\BOI24856\FIG6 3-1.DWG

TABLE 6-3 (continued)

PROCESS OPTIONS RETAINED FOR CONSIDERATION IN THE DEVELOPMENT OF MEDIA-SPECIFIC ACTIONS FOR GROUNDWATER



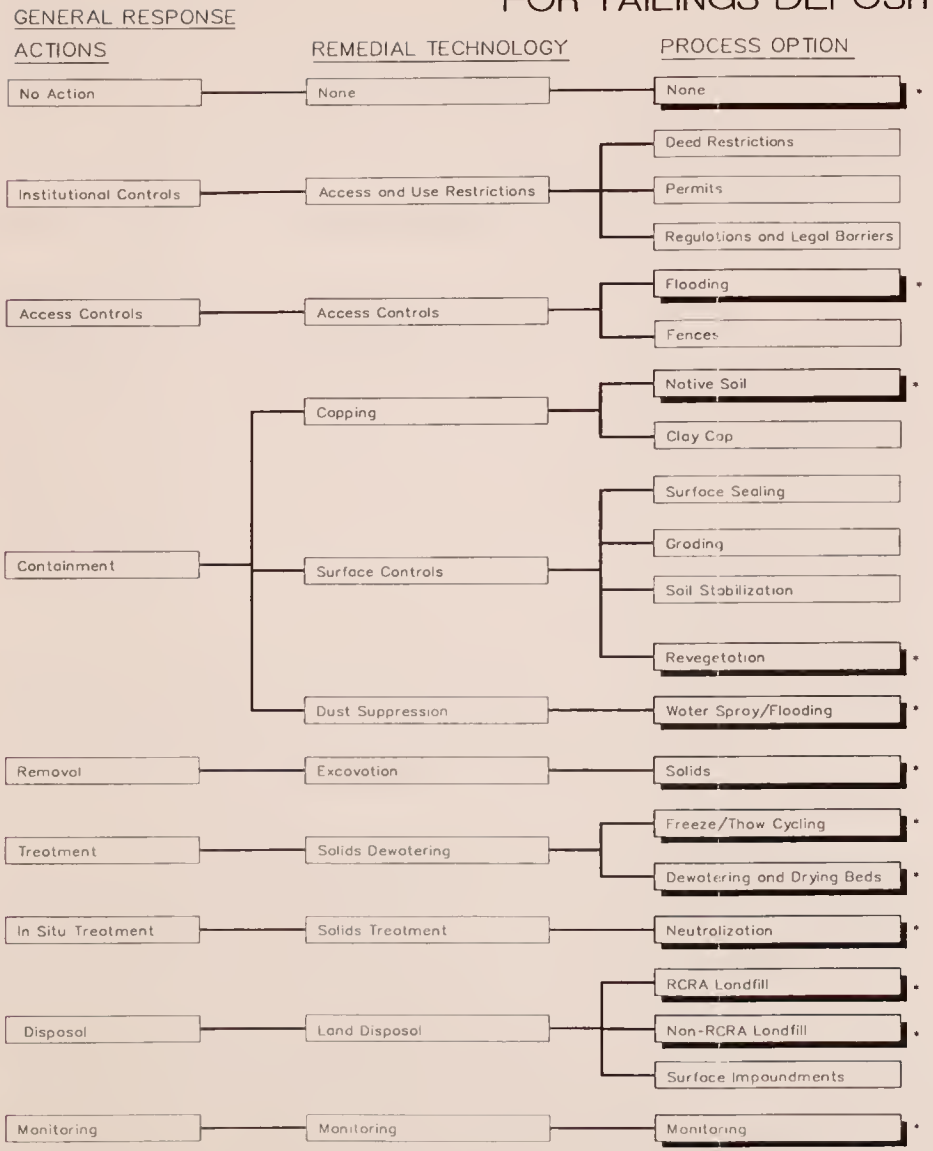
DESCRIPTION
No action.
Deed restrictions issued for property within potentially contaminated areas to restrict property use. May enhance other general response actions.
Regulations promulgated to prohibit aquifer use or require a permit for drilling into aquifers. May enhance other general response actions
Used to remove large amounts of liquid. Liquid must be free of debris.
Wells are installed to collect contaminated groundwater and leachate.
Underground gravel-filled trenches generally equipped with tile or perforated pipe installed to collect contaminated groundwater and leachate
Metals--contaminated water is treated by biological and chemical/physical processes in a wetland.
Metals--contaminated water is treated by biological and chemical/physical processes in a pond.
Aqueous streams are discharged to surface receiving streams.
Short-and/or long-term monitoring is implemented to record site conditions and contamination levels

* Selected for use in assembling media-specific actions. Other process options may later be determined to be more appropriate for use during design or implementation of the remedy.

J \INDUST\80124856\FIG6-3-6.DWG

TABLE 6-3 (continued)

PROCESS OPTIONS RETAINED FOR CONSIDERATION IN THE DEVELOPMENT OF MEDIA-SPECIFIC ACTIONS FOR TAILINGS DEPOSITS AND CONTAMINATED SOILS



DESCRIPTION

No action.

Deed restrictions issued for property within potentially contaminated areas to restrict property use. May enhance other general response actions.

Regulations promulgated to prohibit aquifer use or require a permit for drilling into aquifers. May enhance other general response actions.

No trespassing or other restrictions to limit access and use. May enhance other general response actions.

An area is flooded with shallow water to discourage trespassing.

Security fences installed around potentially contaminated areas to limit access.

Uncontaminated native soil placed over contaminated areas. Soil should minimize infiltration of precipitation.

Compacted clay placed over contaminated areas. Clay should be covered by a layer of silty sand or sandy soil to maintain the integrity of the clay cap.

Cover materials and seal techniques implemented to stabilize waste deposits and to prevent surface water infiltration, control erosion, and isolate and contain the wastes. Similar to capping.

Reshaping of topography to manage surface water, infiltration and runoff to control erosion.

Chemical stabilizers sprayed on bare soils or mulches to coat, penetrate, and bind together the particles. Chemical stabilizers include latex emulsions, plastic films, oil-in-water emulsions, and resin-in-water emulsions.

A systematic revegetation plan includes selection of a suitable plant species, seedbed preparation, seeding/planting, mulching and/or chemical stabilization, fertilization, and maintenance.

Water sprayed over area of concern to prevent dust generation, or flooding of an area to prevent dust generation.

Excavation of contaminated solids can use ordinary construction equipment (backhoes, bulldozers, and front-end loaders).

Some hydroxide sludges that are difficult to dewater are more easily dewatered if frozen and then thawed one or more times.

Sludges placed on sand layered over gravel. Water in the sludge evaporates and drains.

Lime treatment of tailings and contaminated soils prior to capping.

Solid hazardous wastes are permanently disposed of in a RCRA-permitted landfill. RCRA landfills cannot accept liquid hazardous waste.

Solid nonhazardous wastes are permanently disposed of in a non-RCRA landfill. Landfills cannot accept liquid wastes.

Surface impoundments are used to store, dispose, or treat liquid and sludge type waste. Also known as ponds, lagoons, liquid trenches, evaporation ponds, treatment ponds, aeration pits, and stabilization basins.

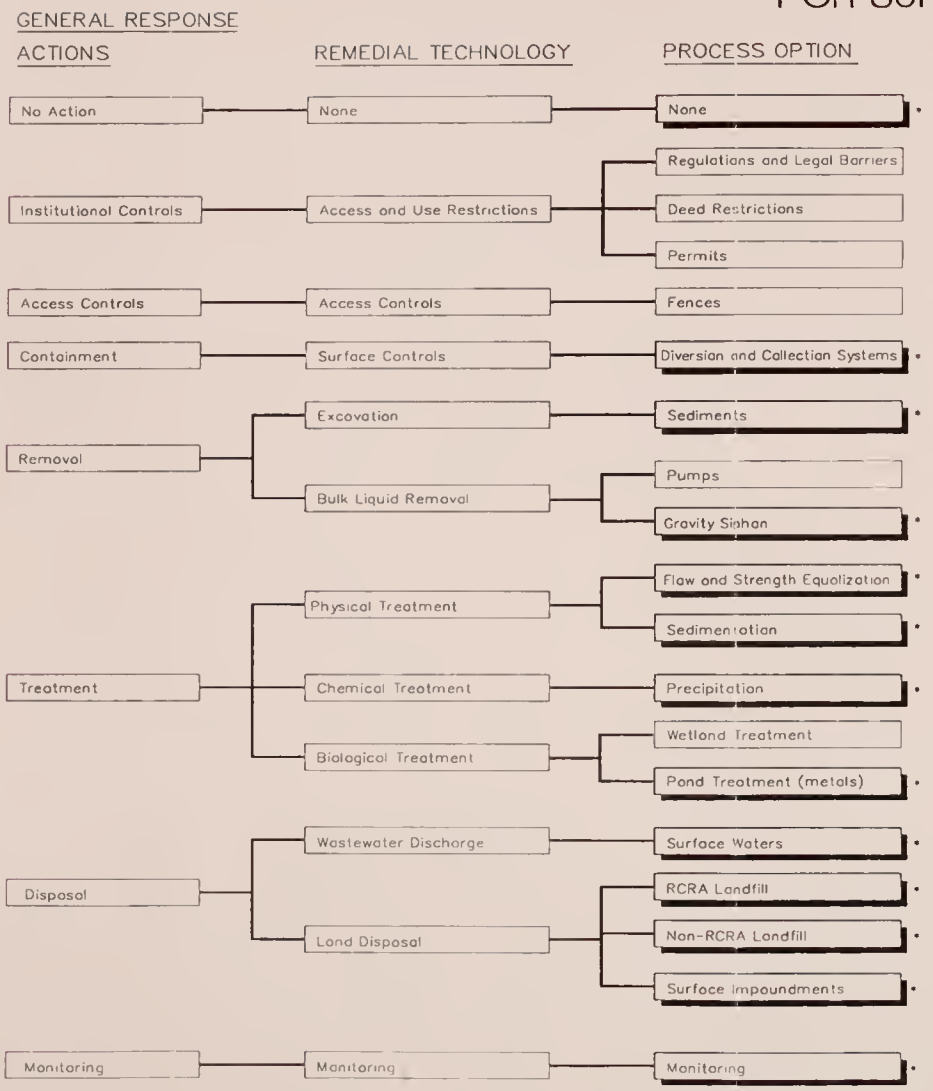
Short and/or long term monitoring is implemented to record site conditions and contamination levels.

J:\INDUST\BOI24856\FIG6-3-4.DWG

* Selected for use in assembling media-specific actions. Other process options may later be determined to be more appropriate for use during design or implementation of the remedy.

TABLE 6-3 (continued)

PROCESS OPTIONS RETAINED FOR CONSIDERATION IN THE DEVELOPMENT OF MEDIA-SPECIFIC ACTIONS FOR SURFACE WATER



DESCRIPTION

No action

No trespassing, and other restrictions to limit access and use. May enhance other general response actions.

Deed restrictions issued for property within potentially contaminated areas to restrict use. May enhance other general response actions.

Regulations promulgated to prohibit aquifer use or require a permit for use. May enhance other general response actions.

Security fences installed around potentially contaminated areas to limit access.

Diversion and collection structures installed upslope or at perimeter of the site to control drainage of stormwater runoff. System can also be implemented to collect contaminated surface water for remediation.

(Excavation of tailings causing contamination of surface water) Excavation of contaminated sediments requires floating equipment or operation of equipment on the bank. Hydraulic dredges, barge-mounted pumps, vacuum trucks, and pneumatic dredges are used for excavation. Generally bulk liquid removal will also be required

Used to remove large amounts of liquid. Liquid must be free of debris.

Used to remove liquids from tanks or ponds Not recommended for flammable, reactive, or shock-sensitive materials.

Equalization basin regulates flow through a treatment facility Mechanical mixing equalizes concentration

Suspended solids removed from liquid by gravity in a tank or lagoon. Sedimentation often preceded by chemical precipitation and/or by coagulation and flocculation.

Chemical equilibria of waste altered to reduce the solubility of heavy metals through the addition of a substance that reacts with the metals or changes the pH or through a change in temperature.

Metals--contaminated water is treated by biological and chemical/physical processes in a wetland.

Metals--contaminated water is treated by biological and chemical/physical processes in a pond

Aqueous streams are discharged to surface receiving streams.

(Disposal of tailings causing contamination of surface water) Solid hazardous wastes are permanently disposed of in a RCRA-permitted landfill. RCRA landfills cannot accept liquid hazardous waste.

(Disposal of tailings causing contamination of surface water) Solid nonhazardous wastes are permanently disposed of in a non-RCRA landfill. Landfills cannot accept liquid wastes.

(Disposal of tailings causing contamination of surface water) Surface impoundments are used to store, dispose, or treat liquid and sludge-type waste. Also known as ponds, lagoons, liquid trenches, evaporation ponds, treatment ponds, aeration pits, and stabilization basins.

Short-and/or long-term monitoring is implemented to record site conditions and contamination levels

• Selected for use in assembling media-specific actions Other process options may later be determined to be more appropriate for use during design or implementation of the remedy

J. \INDUST\BOI24856\FIG6-3-3.DWG

elaboration of the factors contributing to the screening of remedial technologies and process options.

ASSEMBLING MEDIA-SPECIFIC ACTIONS

The study next assembled media-specific actions. Media-specific actions are assembled by combining the selected remedial technologies and process options to address the remedial objectives identified for the operable unit.

In this study, media-specific actions were developed for each of the four site media: pond bottom sediments (three different media-specific actions), surface water (three different media-specific actions), tailings deposits and contaminated soils (four different media-specific actions), and groundwater (two media-specific actions). Twelve media-specific actions were developed in all and they are listed in Table 6-4. Table 6-5 provides some description and discussion of the media-specific actions to clarify the listings in Table 6-4. The media-specific actions are further developed in Chapter 7.

Most feasibility studies would not assemble media-specific alternatives at this point, but rather would proceed directly with assembling the technologies and process options into comprehensive alternatives. However, so long as the interactions among the media do not prevent you from developing separate actions, the assembly of alternatives can be completed later in the feasibility study process.[10] This is the case at the Warm Springs Ponds Operable Unit. While there are some interactions between the media (see Figure 6-1), those interactions do not significantly affect the range of actions that can be developed for the problems identified at the operable unit.

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[10] USEPA, 1988. 1-7, 4-20, and 6-4 to 6-5.

TABLE 6-4
ASSEMBLED MEDIA-SPECIFIC ACTIONS

MEDIA 1: POND BOTTOM SEDIMENTS

Problem 1: POND BOTTOM SEDIMENTS CONTAINMENT - FLOODS

Media-Specific Action 1.

Berm Protection/Raise Berms — Berm Protection/Armor Berms [1]

Media-Specific Action 2.

Pond Closure/Drain/Dewater — Solids Treatment/Soil Cement/ Pozzolanic

Problem 2: POND BOTTOM SEDIMENTS CONTAINMENT - EARTHQUAKES

Media-Specific Action 3.

Berm Stabilization/Flatten Berm Slopes

Media-Specific Action 2.

Bulk Liquid Removal/Gravity/Siphon — Pond Closure/Drain/Dewater — Solids Treatment/Soil Cement/ Pozzolanic

MEDIA 2: SURFACE WATER

Problem 3: FISHKILLS

Media-Specific Action 4.

Excavation/Sediments — Land Disposal/-- [2]

Problem 4: METAL LOADS IN MILL, WILLOW, AND SILVER BOW CREEKS

Media-Specific Action 5.

Surface Controls/Diversion and Collection Systems — Chemical Treatment/ Precipitation — Physical Treatment/ Sedimentation — Biological Treatment/ Pond Treatment — Wastewater Discharge/ Surface Waters

Media-Specific Action 6.

Surface Controls/Diversion Structures — Physical Treatment/Sedimentation — Physical Treatment/ Flow and Strength Equalization — Wastewater Discharge/ Surface Waters

Problem 5: EROSION OF MILL-WILLOW BYPASS TAILINGS INTO CLARK FORK RIVER

Media-Specific Action 4. (repeat)

Excavation/Sediments — Disposal/--

Problem 6: TRANSPORT OF UPSTREAM TAILINGS TO CLARK FORK RIVER

Media-Specific Action 6. (repeat)

Surface Controls/Diversion Structures — Physical Treatment/ Flow and Strength Equalization — Physical Treatment/Sedimentation — Wastewater Discharge/ Surface Waters

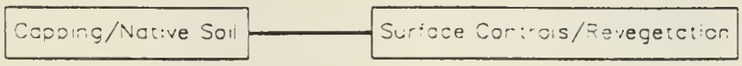
J:\INDUST\B0124856\FIG6-4-1.DWG

TABLE 6-4 (continued)
ASSEMBLED MEDIA-SPECIFIC ACTIONS

MEDIA 3: TAILINGS DEPOSITS AND CONTAMINATED SOIL

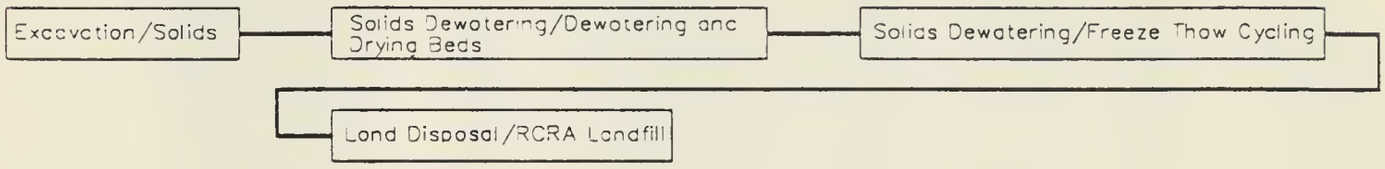
Problem 7: HUMAN AND ENVIRONMENTAL EXPOSURE TO SURFACE CONTAMINATION

Media-Specific Action 7



Media-Specific Action 8.

Media-Specific Action 9.

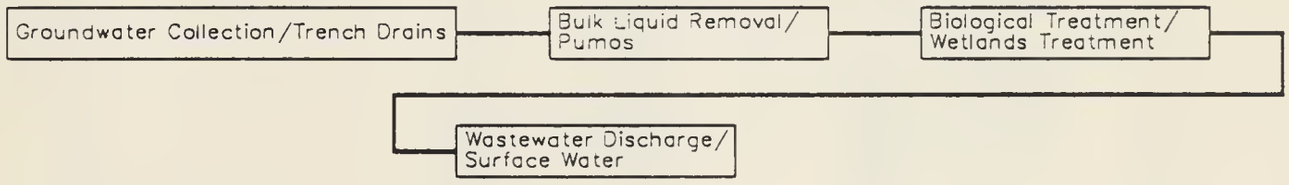


Media-Specific Action 10.

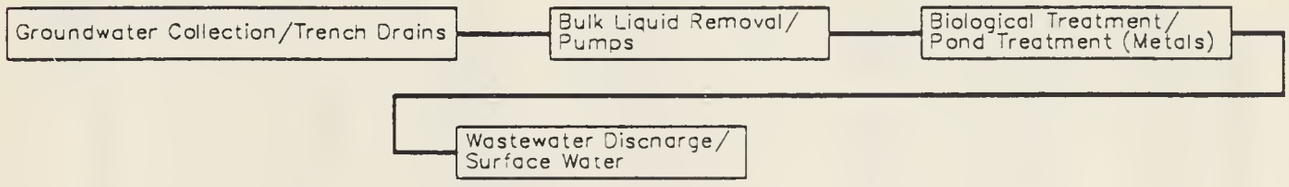
MEDIA 4: GROUNDWATER

Problem 8: CONTAMINATED GROUNDWATER BELOW POND 1 BERM

Media-Specific Action 11.



Media-Specific Action 12.



Note that institutional controls or access controls and monitoring, while not listed in these media-specific actions, may be included to increase and ensure the effectiveness of any of the media-specific actions.

[1] The format for listing technologies and process options is

[2] The process options for disposal are addressed under "MEDIA 3: TAILINGS DEPOSITS AND CONTAMINATED SOIL."

J:\INDUST\BOI24856\FIG6-4-2.DWG

TABLE 6-5
DESCRIPTION OF THE MEDIA-SPECIFIC ACTIONS

MEDIA 1: POND BOTTOM SEDIMENTS

In order to prevent the release of pond bottom sediments during design floods and earthquakes, either the pond berms or the sediments must be stabilized

Media-Specific Action 1.

Berm Protection/Raise Berms — Berm Protection/Armor Berms [1]

The existing containment of the pond bottom sediments would be improved by increasing the height of the berms to avoid overtopping by flood waters and by covering the outer slopes with a protective layer of riprap or other material to reduce the potential for erosion of the berms by flood waters.

Media-Specific Action 2.

Pond Closure/Drain/Dewater — Solids Treatment/Soil Cement

The existing containment of the pond bottom sediments would be improved by reducing their potential for migration (i.e., mobility). This would be accomplished by stabilizing/solidifying the sediments in place. Once stabilized/solidified, the sediments would be less susceptible to migration from the action of floods and earthquakes, even if the pond berms were seriously damaged, because they would no longer be erodible by the flood waters or susceptible to flowing. All of the tailings deposits and contaminated soils (Media 3) in the operable unit would also be solidified in the ponds as a permanent disposal action.

Media-Specific Action 3.

Berm Stabilization/Flatten Berm Slopes

The existing containment of the pond bottom sediments would be improved by upgrading the berms to withstand, without serious damage, the destructive forces of a design earthquake. This would be accomplished by flattening the slopes of the berms (i.e., increasing the width of the berms at their base)

MEDIA 2: SURFACE WATER

In order to attain compliance with the water quality standards for acquatic life and public health and maximum contaminant levels, it will be necessary to reduce the potential for exceedances of both the acute and the chronic standards over both the short term and the long term.

Media-Specific Action 4.

Excavation/Sediments — Land Disposal/--

The potential for short-term exceedances of the acute water quality standards for aquatic life (such exceedances have been the cause of several fishkills) would be reduced by removing the exposed tailings and contaminated soil from the Mill Willow Bypass. This media-specific action would also help to reduce the potential for exceedances of the chronic and acute water quality standards for aquatic life and public health standard over the long-term in the Clark Fork River. The action would eliminate the potential for the exposed tailings currently in the bypass to be eroded by high flow events and transported to the Clark Fork River. The disposal process option would be determined by the process option(s) chosen for the exposed tailings and contaminated soils medium (see below).

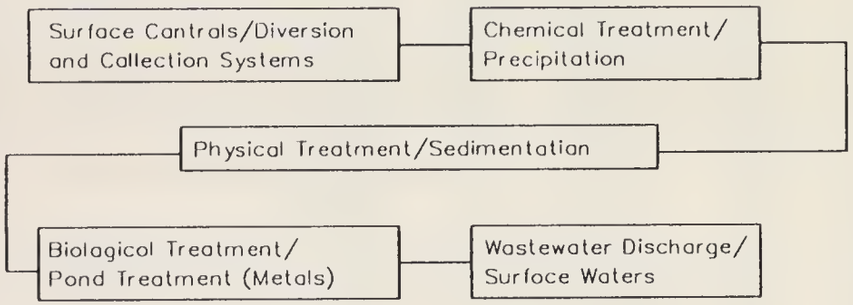
[1] The format for listing technologies and process options is

Technology/Process Option

J:\MDT\180246\6\TABLE 6-5.DWG

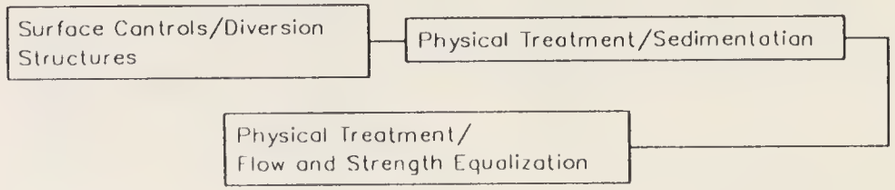
TABLE 6-5 (Continued)
DESCRIPTION OF THE MEDIA-SPECIFIC ACTIONS

Media-Specific Action 5.



To meet the chronic water quality standards for aquatic life in the Mill-Willow Bypass at the compliance point, treatment of the flows in Silver Bow Creek will have to be continued and improved. In addition, the flows in Mill and Willow Creeks will have to be treated. The continuing, improved treatment of contaminated creek flows would be provided by a pond treatment system: either a modified version of the existing system or a new treatment pond. As described in Chapters 2 and 7, the existing pond system treats the contaminated waters by a combination of chemical precipitation of dissolved metals, sedimentation of particulates, and a complex biological process that removes dissolved metals. A new pond system would use the same treatment process.

Media-Specific Action 6.

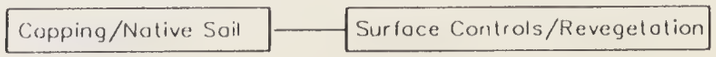


To provide for attainment of both the acute and chronic water quality standards for aquatic life over the long-term, both within the operable unit and in the Clark Fork River, it is necessary to reduce the potential for transport of suspended tailings and contaminated soils eroded from upstream areas. This could be accomplished either by reducing the potential for the tailings and contaminated soils to be eroded by floods, or by providing a settling basin upstream of the operable unit to trap the majority of the tailings and soil particles carried by flood waters. For the purposes of this feasibility study, the possibility of providing either a large flood impoundment or a smaller settling basin are explored (see Chapter 7). In addition to providing settling capacity, a new pond can provide flow equalization to allow metering flood waters into the pond treatment system for treatment to remove dissolved metal contaminants.

MEDIA 3: TAILINGS DEPOSITS AND CONTAMINATED SOIL

In order to reduce the human health and environmental threats associated with tailings deposits and contaminated soils, the potential for human and environmental exposure to the tailings and soils must be decreased.

Media-Specific Action 7.



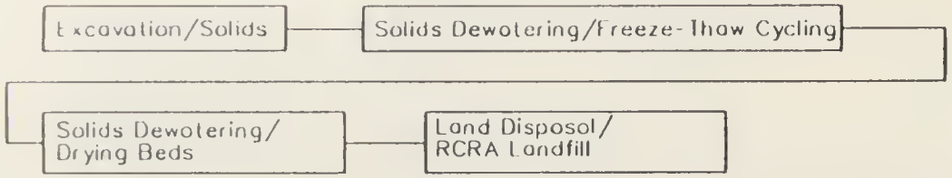
The potential for exposure to the tailings deposits and contaminated soils would be reduced by placing barriers over the areas of surface contamination. The barriers would be a layer of native soils vegetated with native species to protect the surface contamination from erosion or disturbance. The barriers would reduce the potential both for direct human contact with contaminants and for migration of the contaminants through the air pathway.

Media-Specific Action 8.

The potential for exposure to the tailings deposits and contaminated soils would be decreased by flooding contaminated areas with shallow water. This would reduce both the potential for direct human contact with the contaminants and for migration of the contaminants through the air pathway.

TABLE 6-5 (Continued)
DESCRIPTION OF THE MEDIA-SPECIFIC ACTIONS

Media-Specific Action 9.



The potential for exposure to the tailings deposits and contaminated soils would be decreased by removing the tailings and soils from the operable unit and disposing them in an existing, offsite, RCRA permitted landfill

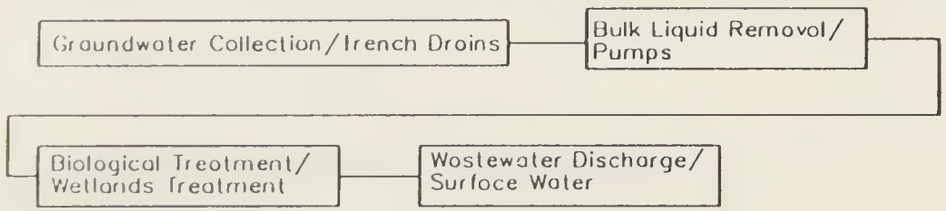
Media-Specific Action 10.

The potential for exposure to the tailings deposits and contaminated soils would be decreased by excavating the tailings and soils and disposing them onsite in a landfill for non-hazardous wastes. Disposal would be in Pond 1 either prior to solidification (Media-Specific Action 2) or prior to capping (Media-Specific Action 7)

MEDIA 4: GROUNDWATER

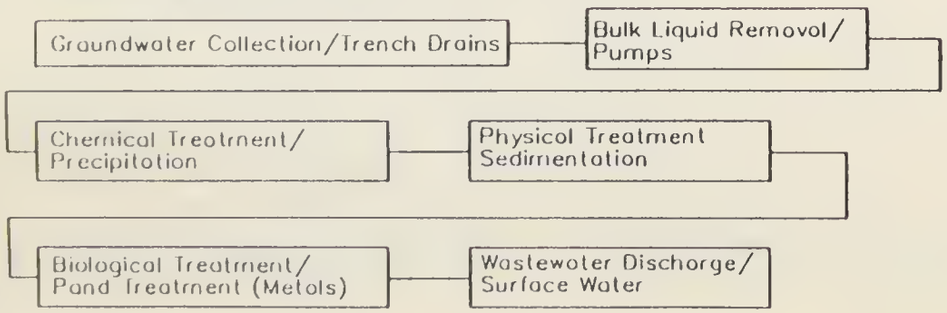
Media-Specific Action 11.

In order to achieve compliance with maximum contaminant levels, the groundwater must be removed and treated

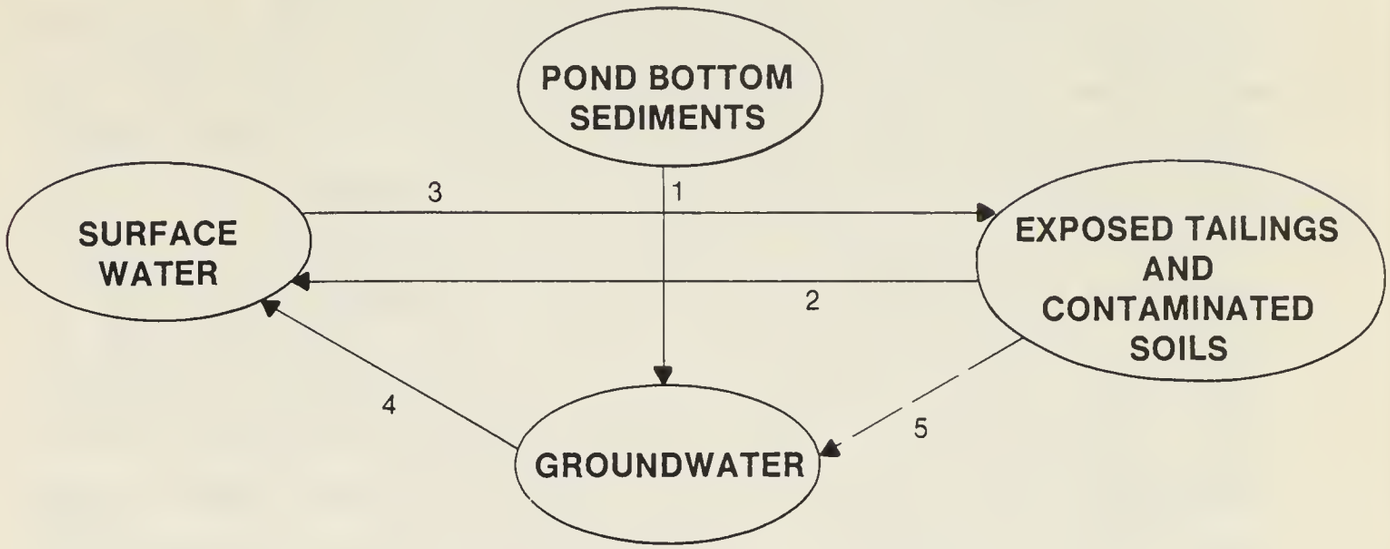


Attainment of maximum contaminant levels would be accomplished by collecting the groundwater in trenches, pumping it to the surface, and treating it in a wetland prior to discharging it to the Clark Fork River.

Media-Specific Action 12.



Attainment of maximum contaminant levels would be accomplished by collecting the groundwater in trenches, pumping it to the surface, and piping it to the inlet of the pond treatment system for treatment along with the surface waters.



NOTES:

1. POND 1 SEDIMENTS ARE THE MAJOR SOURCE OF GROUNDWATER CONTAMINATION BELOW POND 1.

2. EXPOSED TAILINGS AND CONTAMINATED SOILS ARE A CONTINUING SOURCE OF METAL IONS TO THE SURFACE WATERS, PARTICULARLY THE BYPASS, WHERE THEY CAUSE FISHKILLS.

3. THE EXPOSED TAILINGS AND CONTAMINATED SOILS WERE DEPOSITED AT THEIR CURRENT LOCATIONS BY THE SURFACE WATER FLOWS. THE SURFACE WATER IS A CONTINUING SOURCE FOR FUTURE DEPOSITS OF TAILINGS.

4. CONTAMINATED GROUNDWATER DISCHARGES TO THE SURFACE WATER BELOW POND 1, AND ALSO TO THE CLARK FORK RIVER.

5. SOME SMALL AREAS OF THE TAILINGS BELOW POND 1 ARE BELOW THE WATER TABLE AND ARE SUSPECTED OF CONTRIBUTING TO THE CONTAMINATION IN THE GROUNDWATER IN THAT AREA.

FIGURE 6-1

INTERACTIONS BETWEEN THE MEDIA AT THE WARMS SPRINGS PONDS OPERABLE UNIT

WARM SPRINGS PONDS
FEASIBILITY STUDY

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The known interactions between the media are discussed in the following paragraphs.

The pond bottom sediments are known to be the major source of the contaminants in the groundwater below Pond 1. The interaction of the pond bottom sediments with the groundwater does not affect the types of remedial actions that can be developed for the pond bottom sediments. The main problem presented by the sediments is their potential for release in the event of a flood or an earthquake. Alternatives for protecting the pond bottom sediments from catastrophic releases can be developed without simultaneously addressing the contribution of the sediments to the groundwater contamination. The groundwater problem cannot be effectively addressed by source control actions taken on the pond bottom sediments. The only source control action that would, in principle, decrease the contribution of the Pond 1 sediments to the groundwater contamination would be removal of the sediments; this technology was screened out in Table 6-2 due to its technical infeasibility. The groundwater contamination problem must instead be addressed by direct actions taken to extract and treat the groundwater, and perhaps to intercept some of the groundwater before it becomes contaminated and divert it around Pond 1.

The tailings deposits are known to contribute to the surface water contamination by releasing metal ions to the flows. This has been discussed previously, particularly in Chapter 4, as the cause of the fishkill problem. Besides the acute contamination problem resulting in the fishkills, the tailings and contaminated soils also contribute smaller amounts of contaminants to the surface water on a chronic basis. This interaction between the exposed tailings and the surface water does not affect the alternatives that can

be developed for either of these two media. In both cases, actions must be taken to isolate the tailings.

The surface water is known to be the source of the tailings deposits and contaminated soils along the bypass and in other areas of the operable unit, and can be expected to bring additional deposits in the future if nothing is done to remove the tailings from the flows in the creeks, or to prevent the erosion of the upstream tailings deposits. This interaction between the surface water and the tailings deposits and contaminated soils will be significant in determining the long-term effectiveness (permanence) of any actions that might be taken to remove the existing tailings and contaminated soils. Specifically, some actions must be taken to prevent future deposits or to remove such deposits as they collect. Otherwise, new tailings and contaminated soils will build up, the cleanup will prove to be only temporary, and fishkills will again become a possibility.

However, this interaction does not affect the alternatives that can be developed to address the tailings that are already in the bypass. The existing tailings and contaminated soils have to be addressed by actions taken separately from those for addressing the potential for future deposits. The possibility of future deposits has to be addressed by either source control actions on the upstream sediments (part of a later feasibility study on a different operable unit), or by treating the contaminated flows to remove the suspended solids (addressed in this feasibility study).

The groundwater is known to affect the contamination levels in the surface water north of Pond 1, and in the Clark Fork River. This interaction does not affect the alternatives

that can be developed to address the groundwater contamination. The groundwater must be extracted and treated. Extracting the groundwater for treatment will effectively address the problem of the groundwater contaminating the surface water by reducing the discharge of the contaminated groundwater to the surface water bodies.

RANGE OF THE MEDIA-SPECIFIC ACTIONS

There are certain features of the operable unit that tend to reduce the range of technologies that can be implemented. The following subsections discuss the reasons for the limited range of media-specific actions identified in Table 6-4.

POND BOTTOM SEDIMENTS

Pond Bottom Sediment Containment--Floods

To prevent the pond bottom sediments from being released during a flood, it will be necessary to either remove them from the floodplain so they are not subject to floods, to improve the pond berms so that they will survive a flood substantially unharmed, or to stabilize the pond bottom sediments so that if the berms are damaged by a flood the sediments will not be released.

As noted in Table 6-2, excavation and removal of the tailings was screened out because its implementation would be extremely difficult and impractical. The volume of the sludges is too large to allow this approach to be readily implemented. The sediments would have to be dewatered prior to excavation. This alone could take decades to complete because the sediments are of a type that is very difficult

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to dewater. Once dewatered, the excavation and removal would take several additional years and require over a million truck trips. Added to this is the problem of providing an acceptable disposal site for so large a volume of wastes.

If the berms are to be upgraded to withstand a flood, only one approach will meet the remedial objective of keeping the sediments in the ponds: raising and armoring the berms so they will not be overtopped or damaged by a design flood. The only other approach that is used to protect berms from high flows is installing a spillway. A spillway allows a high flow to pass through and out of a pond, over the berm, without damaging the berm. Such an approach would not be effective in meeting the remedial objective because the large flows passing through the ponds would scour a substantial fraction of the sediments from the pond bottoms and wash them out of the pond system.

There are several ways to armor the berms, but those are design details that are discussed in the next chapter and will only be ultimately decided during the final design phase. There is also a range of design floods against which protection could be provided. The selected design flood will determine the final height of the berms. All of these variations fall under the same media-specific action of raising and armoring the berms.

If the sediments are to be stabilized, their large volume calls for an in situ stabilization process. The in situ stabilization process would be less difficult and less costly than excavation and handling of the wastes. A pozzolanic (cement-like) process was selected because it is apt to be less expensive than polymer admixtures, and because there is a technology for pozzolanic in situ stabilization that has been demonstrated on a large scale.

No other means of stabilizing such large volumes of gelatinous sludges was identified.

Pond Bottom Sediments Containment--Earthquakes

Two options exist to prevent the pond bottom sediments from being released during an earthquake: improve the pond berms so they will survive an earthquake substantially unharmed; or stabilize the pond bottom sediments so that if the berms are damaged by an earthquake, the sediments will not be released. The general response action of removal would not, by itself, be effective. Moving the sediments to another location would not be an effective solution unless a disposal site substantially lower in seismic susceptibility could be found. This could require moving the sediments many miles, and would involve the other problems noted above for the dewatering, excavation, and transport of the sediments. Even if the sediments could be moved to a seismically stable facility nearby, but this would be much more expensive and no more effective than improving the seismic stability of the existing ponds.

If the berms are to be upgraded to withstand an earthquake, there are two approaches that are acceptable from an engineering point of view--flattening the slopes of the berms so they will not be damaged by an earthquake, or adding material (weight) just at the toe of the berm rather than along its full height. Either approach is potentially usable at Warm Springs Ponds. Flattening the slopes of the berms was selected for use in this study because it may be less expensive than adding material at the toe of the berms.

The discussion in the preceding subsection regarding in situ stabilization applies as well to stabilizing the sediments so they would not move if an earthquake damaged the berms.

SURFACE WATER

Fishkills

In Chapter 4, the major cause of the fishkills was identified as the tailings deposits in the Mill Willow Bypass. In order to prevent future fishkills from this cause, it will be necessary to isolate the flows in the bypass from the tailings. This can be done either by removing the tailings from the bypass or by installing a barrier between the tailings and the flows so that the contaminants in the tailings cannot reach the water in the bypass. Two examples of barriers that were considered are installation of a culvert for the flows in the bypass, and lining the bypass with a paving material such as concrete.

A media-specific action incorporating construction of a barrier was not assembled because it would be more expensive and less effective than simply removing the tailings. Removal of the tailings is expected to solve the problem, as long as new deposits of tailings are not allowed to accumulate in the bypass. A barrier would simply act to restrict movement of the tailings already in place. Construction of a barrier is not specifically screened out in Table 6-2 because the process option that it would fall under, "Diversion and Collection Systems," is needed for other surface water-specific actions in the following subsections.

Thus, one media-specific action is identified for solving the fishkill problem--removing the tailings from the bypass.

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Metals Loads in the Flows of Mill, Willow, and Silver Bow Creeks

Two options exist to protect the Clark Fork River from the contaminated flows of the three creeks: control or eliminate the sources of the contaminants so the three creeks will no longer be contaminated; or provide treatment of all flows until the sources can be controlled or eliminated.

This operable unit feasibility study does not examine the possibility of controlling or eliminating the upstream sources of the dissolved metals and tailings. The majority of the sources are miles upstream and are not part of the operable unit addressed in this study. As noted previously, they will be addressed in separate feasibility studies. In addition, even if upstream sources are controlled, continued treatment and protection may be needed.

As noted in Chapters 2 through 5, the current treatment system is not adequate to meet the chemical-specific ARARs identified for the surface waters. The available treatment capacity will have to be upgraded, and the system changed to include treatment of Mill and Willow Creeks, if the ARARs are to be met. There are two ways to provide continuing, upgraded treatment: upgrading the existing pond treatment system, or replacing the existing system with a new one that can meet the chemical-specific ARARs.

Both of these approaches to upgrading the currently inadequate treatment system are developed in the next chapter. Briefly though, either of these two approaches would use the same basic method of treatment as currently used. That is, neither an upgrading of the existing system nor a new system would use a different combination of technologies and process options from that currently being used. No more effective or less expensive treatment technology is available for

flows as large as the treatment system has to handle. Therefore, both alternatives fall under the same media-specific action (Number 5).

Erosion of Mill Willow Bypass Tailings into the Clark For River

There are three ways to keep the tailings in the bypass from eroding during high flow events: stabilize the tailings to resist erosion, contain the tailings by means of a barrier that prevents movement, or remove the tailings from the bypass.

Either stabilizing or containing the tailings would be less implementable, less effective, and more expensive than removing them. For this reason, and because removing the tailings is required in order to solve the fishkill problem, one media-specific action was assembled for this problem--removing the tailings from the bypass.

Transport of Upstream Tailings to the Clark Fork River

The tailings deposited along Silver Bow Creek and occurring to lesser extents in Mill and Willow Creeks are eroded by water flowing in the creeks and carried through the operable unit into the Clark Fork River. Small amounts of tailings are probably eroded continuously by normal flows in the creeks; suspended solids measured in the surface water are partly tailings. During normal flows, the tailings in Silver Bow Creek, but not those in Mill and Willow Creeks, are settled out in Pond 3. During higher flows and floods, the Silver Bow Creek flows are diverted around the ponds and go directly to the Clark Fork River.

Pond 3 cannot be used to settle out the tailings during high flows and floods because its calculated allowable maximum flow rate of 600 cfs is substantially below flood flow levels. At flows much above 600 cfs, sediments already in the pond could be reentrained near the discharge structures and the water could leave Pond 3 more contaminated than when it entered.

To protect the Clark Fork River from being the ultimate repository of much of the approximately 3 million cubic yards of tailings upstream of the operable unit, one of three actions will be necessary: 1) stabilize or contain the upstream tailings so they are not susceptible to erosion, 2) remove the tailings from the upstream creek beds and banks, or 3) provide additional detention and settling capacity to settle the tailings out during high flow events. This study focuses on the media-specific action of providing upstream detention and settling capacity for interim protection pending upstream cleanups, and for protection during catastrophic events. This will require construction of a new impoundment upstream of Pond 3.

TAILINGS DEPOSITS AND CONTAMINATED SOILS

Unlike the other media, the range of media-specific actions for tailings deposits and contaminated soils is not limited. Several alternatives are possible and develop for this site problem.

GROUNDWATER

Contaminated Groundwater Below Pond 1

In general, contaminated groundwater can be either treated in place, or removed, treated, and discharged. In situ

treatment is generally limited to organic contaminants that can be degraded by biological processes. However, the groundwater in the operable unit is contaminated by inorganic contaminants. None of the existing in situ remedial technologies for inorganic groundwater contaminants would be effective at the Warm Springs Ponds Operable Unit. Therefore, attaining groundwater ARARs below Pond 1 will require extracting the groundwater, and treating and releasing it.

Two methods are generally used to extract groundwater: wells and trench drains. Either method could be used at Warm Springs Ponds. However, a large number of wells would be required to extract the groundwater. The effectiveness of trench drains would be more certain, and trench drains would be less expensive over the long term than a well system. Therefore, trench drains were selected as the representative process option, and no media-specific actions were assembled using wells as the extraction method.

The extracted groundwater would be treated to remove the dissolved metals. This could be accomplished by constructing a wetland in the area below Pond 1 and using the wetland to treat the extracted groundwater prior to discharge to the Clark Fork River, or by pumping the groundwater through a pipe to Pond 3 for treatment.

Wetland treatment is an innovative technology that provides some advantages for this application. It would flood an area that is currently contaminated. Removal of tailings deposits and contaminated soils prior to construction of the wetland is considered in the development of the media-specific actions in Chapter 7.

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Chapter 7
DETAILED DEVELOPMENT OF THE MEDIA-SPECIFIC ACTIONS

The purpose of any remedial action undertaken at the Warm Springs Ponds Operable Unit will be to protect human health and welfare and the environment, and to attain compliance with the applicable or relevant and appropriate requirements. These requirements have been determined for each of the contaminated media.

For the pond bottom sediments, the principal applicable requirements are those set forth in the Montana Department of Natural Resources and Conservation dam safety regulations. These regulations require that the berms, if left in place, be protected from serious damage by certain specified design floods (i.e., 0.2 PMF, 0.3 PMF, and 0.5 PMF for Ponds 1, 2, and 3, respectively), and that the berms be built to withstand a maximum credible earthquake without serious damage. A static safety factor of 1.5 and a seismic safety factor of 1.2 will also be required.

For the surface water, the principal applicable or relevant and appropriate requirements are the Montana water quality standards for aquatic life and public health protection.

For the tailings deposits and contaminated soils, there is no applicable or relevant and appropriate requirement for cleanup. However, for the purpose of this feasibility study, two target cleanup levels have been selected. Areas of tailings deposits and contaminated soils containing concentrations over 250 parts per million of arsenic and/or

containing over 750 parts per million of lead are designated for remediation. This will reduce the threats to human health which the Public Health and Environmental Assessment has identified as attendant to such levels of contamination.

For the groundwater, the applicable or relevant and appropriate requirements are the Montana primary maximum contaminant levels. Areas of aquifers contaminated at levels above the maximum contaminant levels (specifically, the area below Pond 1 delineated in Figure 2-20 as exceeding the primary maximum contaminant levels for arsenic and cadmium) would be remediated to reduce the contamination to below the maximum contaminant levels.

In the preceding chapter, the remedial technologies and process options were screened and selected process options were assembled into media-specific actions to achieve these applicable or relevant and appropriate requirements and target cleanup levels. Twelve media-specific actions were assembled to address the four site media (i.e., pond bottom sediments, surface water, tailings deposits and contaminated soils, and groundwater). This chapter develops each of the media-specific actions in detail, indicating calculations, process flow analyses, layouts, and sizing of the various components. Some of the media-specific actions are developed as more than one option to provide a range of options where possible. The media-specific actions will be combined in Chapter 8 to develop comprehensive alternatives for the entire operable unit, which will then be evaluated in detail in preparation for the ultimate selection of an appropriate remedy.

The 12 media-specific actions (including options) are listed in Table 7-1.

Table 7-1
MEDIA-SPECIFIC ACTIONS DEVELOPED
FOR THE WARM SPRINGS PONDS OPERABLE UNIT
FEASIBILITY STUDY

POND BOTTOM SEDIMENTS

1A. Stabilize pond berms to withstand a probable maximum flood (PMF)

1B. Stabilize pond berms to withstand fractions of a PMF (Pond 3, a 0.5 PMF; Pond 2, a 0.3 PMF; Pond 1, a 0.2 PMF)

2. Solidify pond bottom sediments

3. Stabilize pond berms to withstand a maximum credible earthquake

SURFACE WATER

4. Remove exposed tailings and contaminated soils from along the bypass

5A. Comprehensive upgrade of the current Pond 3 system

5B. Partial upgrade of the current Pond 3 system: replace the fuse plug, improve the trashrack, and improve the lime addition system

5C. Construct a new treatment pond

6A. Construct an 8,000-acre-foot upstream flood impoundment

6B. Construct 2,000-acre-foot upstream settling basin

TAILINGS DEPOSITS AND CONTAMINATED SOILS

7. Cap and revegetate all applicable areas

8. Flood all applicable areas

9. Excavate from all applicable areas; disposal in an offsite RCRA facility

10. Excavate from all applicable areas; disposal in an onsite waste repository (Pond 1) either prior to solidification (Media-Specific Action 2) or capping (Media-Specific Action 7)

GROUNDWATER

11. Install trench drain below Pond 1; treat groundwater in onsite wetlands

12. Install trench drains in and below Pond 1; treat groundwater in Pond 3

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MEDIA-SPECIFIC ACTION 1: STABILIZE POND BERMS TO WITHSTAND FLOODS

The existing western pond berms along the Mill-Willow Bypass are susceptible to failure due to overtopping or scour during a major flood event in the Mill, Willow, Silver Bow Creeks system. In addition, the ponds are susceptible to flooding and potential overtopping of the berms from large storm events in the hills east of the ponds.

This media-specific action for the pond bottom sediments proposes measures to protect the berms from scouring or overtopping during various flood events. Media-Specific Action 1A would provide protection against a probable maximum flood (PMF). Media-Specific Action 1B details measures to protect against lesser flood events ranging from a 0.2 to 0.5 PMF, depending upon which pond is being considered.

MEDIA-SPECIFIC ACTION 1A: STABILIZE POND BERMS TO WITHSTAND A PROBABLE MAXIMUM FLOOD

This media-specific action was developed to address protection of the existing pond berms from catastrophic failure due to a probable maximum flood. Three discrete actions would be incorporated into Media-Specific Action 1A. These include:

- Raise and armor the pond berms along the Mill-Willow Bypass to protect against a PMF in the Silver Bow and Mill-Willow drainages.
- Reconstruct the Mill-Willow Bypass, as necessary.
- Provide protection of the ponds from storm runoff from the hills to the east.

The components of this media-specific action are shown in Figure 7-1. The details are discussed in the following subsections:

Protect Pond Berms Along Mill-Willow Bypass from a PMF

The existing pond berms along the Mill-Willow Bypass would be overtopped in places during a probable maximum flood in the Silver Bow and Mill-Willow drainages. The PMF has been estimated to be 146,000 cfs in the vicinity of the Warm Springs Ponds.[1]

A flood modeling program (HEC-2) indicated that PMF flows would overtop the western berms of Ponds 2 and 3 in several places, especially toward the south where the berms provide the lowest level of protection. Inundation of the ponds by a PMF would result in at least partial scour of the existing sediments and potential catastrophic failure of the berms due to lack of adequate means to handle these flows within the pond system.[2] Floods through the ponds would scour a channel through the sediments and would be unlikely to entrain all the material and convey it downstream.

To avoid having a PMF spill into the Warm Springs Ponds, it would be necessary to raise the crests of the existing embankments in many places. The flood modeling program was rerun assuming an artificial constraint along the western berms to determine PMF hydraulics following berm raising. Figure 4-4 shows the inundation for a PMF assuming this artificial constraint.

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[1] CH2M HILL, 1988. Draft Silver Bow Creek Flood Modeling Study. Prepared for the State of Montana Department of Health and Environmental Sciences, Helena, Montana.

[2] Ibid.

This simulation indicated that the berms would have to be raised along approximately two-thirds of their length, in some places by as much as 14 feet, to avoid overtopping.[3]

For this study, it was assumed that the berms would be raised using imported, well-graded gravels. In most places, the new construction would occur on the outside (nonwater side, see Figure 7-1) of the berms to avoid the need for dewatering in the ponds. The raised portions of the berms would be constructed at a maximum slope of 2.5:1 (horizontal:vertical).

This media-specific action assumes the berms would be modified along their current alignments. The conceptual design does not include relocating any of the berms. During the design phase, it may prove cost-effective to realign the Pond 3 berm to follow the southern edge of the present water surface, over to the base of the eastern hills. Constructing a new flood-protection berm along this alignment would probably require less material than raising the height of the existing berm. This variation was not further developed in this feasibility study, nor was a cost estimate prepared.

The outside of the berms along the Mill-Willow Bypass would be armored with riprap to avoid failure of the berms caused by scour from floods up to a PMF.[4]

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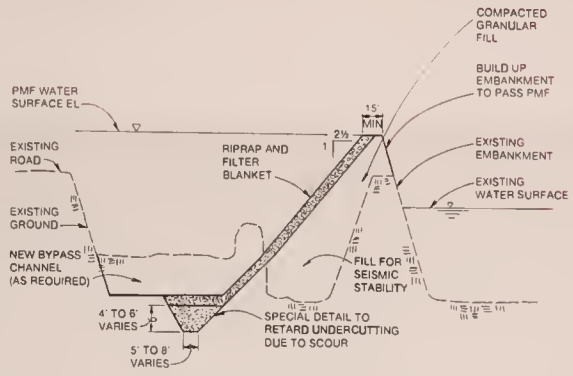
[3] CH2M HILL, 1988.

[4] Either soil cement or riprap could be used to stabilize the berms. Both would provide adequate stabilization and comparable long-term effectiveness. The selection of one means of stabilization over the other will likely be based on economics and made during the predesign or design phase of the project. For purposes of this feasibility study, riprap was assumed to be the selected material and is referred to throughout the remainder of the report.



TYPICAL RECONSTRUCTION OF DIKE FOR PMF AND MAXIMUM CREDIBLE EQ

SECTION A-1

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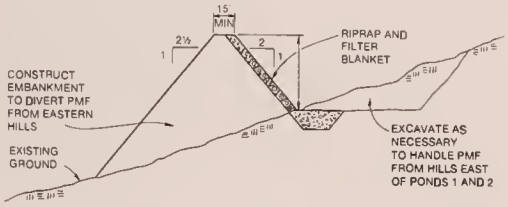

SECTION B-1

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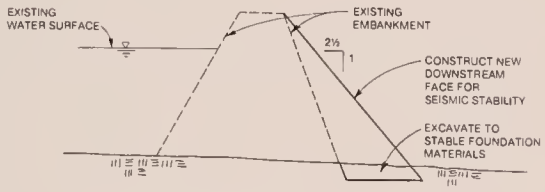

TYPICAL EMBANKMENT RECONSTRUCTION FOR SEISMIC STABILITY

SECTION C-1

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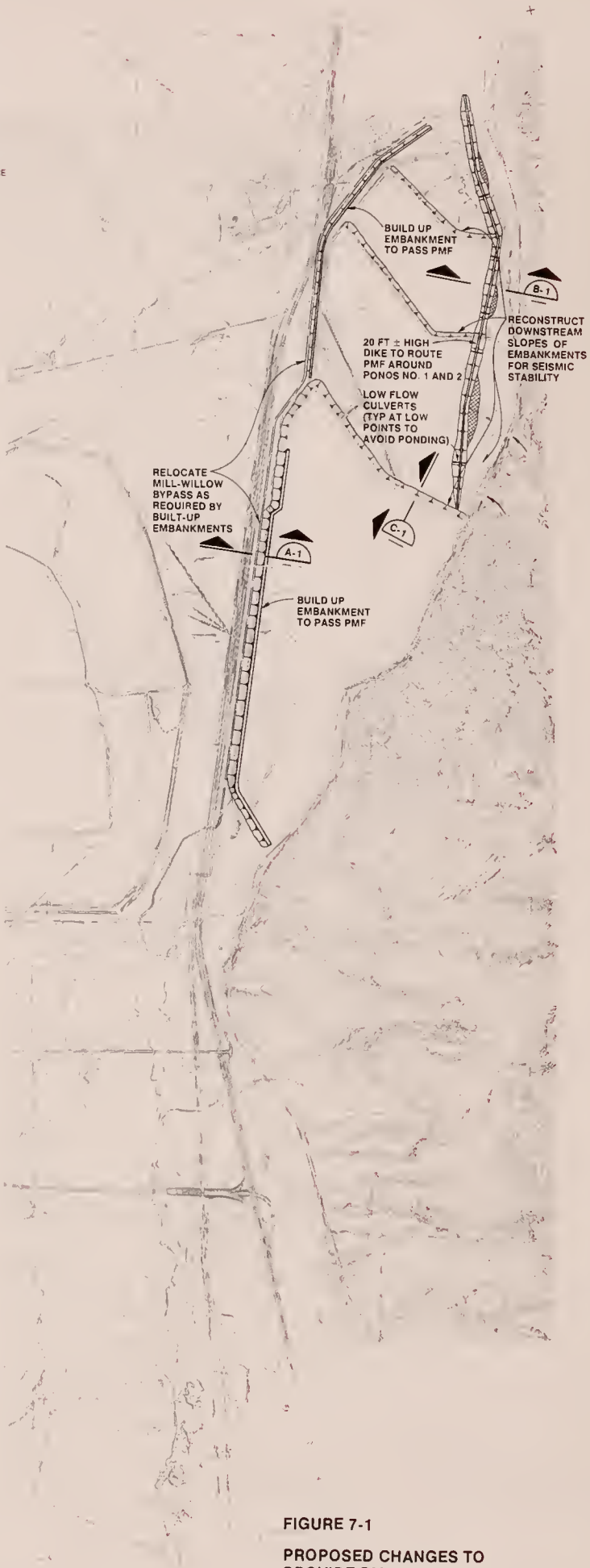

FIGURE 7-1

PROPOSED CHANGES TO PROVIDE PMF AND EARTHQUAKE PROTECTION
MEDIA-SPECIFIC ACTIONS 1A & 3
WARM SPRINGS PONDS
FEASIBILITY STUDY

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The flood modeling program estimated velocities of 16 to 21 feet per second (fps) along the berms during a PMF, depending on location.[5] A preliminary riprap design based on these velocities indicated that 60- to 300-pound rock would be required. Assuming dumped riprap, the required thickness would vary from 3 to 5 feet.[6] A filter blanket or geotextile mat between the riprap and the embankment also would be required.

Reconstruct the Mill-Willow Bypass

In some locations where the berms on the west side of the ponds must be raised to keep a PMF out of the ponds or modified for seismic stability (see Media-Specific Action 3), the new embankments would cover the existing Mill-Willow Bypass channel. In these locations, it would be necessary to construct a new channel at the toe of the embankments. The new channel would be designed with the same flow capacity as the existing channel. The new channel would be lined with riprap, as necessary, to protect against scour.

Flood Control Berm Along East Side of Ponds

Storm runoff from the hills east of the ponds currently drains into the ponds in an uncontrolled manner. A large storm in these hills could damage the pond system.

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5 CH2M HILL, 1988.

6 Caltrans, 1970. Bank and Shore Protection in California Highway Practice. Sacramento, California.

Based on a previous study,[7] a probable maximum flood from the hills east of the ponds would have estimated flows as shown in Table 7-2.

Table 7-2
STORAGE CAPACITY OF PONDS

	Drainage Area (sq. mi.)[a]	Peak Discharge (cfs)	Volume (ac-ft)	Storage Available within Existing Berms (ac-ft)
Pond 1	3.80	13,800	2,200	2,000
Pond 2	5.27	19,200	3,000	1,700
Pond 3	1.73	9,700	1,000	3,000

[a]IECO, 1981.

As can be seen, the storage capacity in Pond 3 is sufficient to store these flows within the existing berms. The flows would be allowed to come into Pond 3 and would result in an increase in water surface elevation of about 1.4 feet.

Ponds 1 and 2 must be protected from PMF flows from the east, however, to avoid berm breaching and sediment scour. Pond protection would be accomplished by diverting a PMF around the east edge of Ponds 1 and 2. An embankment 20 to 30 feet high would be designed along the eastern edge of the ponds to direct the flood flows from the eastern hills north around the ponds to the Clark Fork River. The upstream face of the embankment should be armored with riprap to protect against scour. Culverts would be designed through the embankment at low points and at existing washes to allow

7 International Engineering Company (IECO), 1981. Geotechnical and Hydrologic Studies of the Warm Springs Tailings Ponds, Anaconda, Montana. Prepared for the Anaconda Copper Company, Denver, Colorado.

small flows through the embankment to the ponds and to avoid the accumulation of stagnant water at low points. Because sediment and debris would deposit along the embankment during flood discharge, periodic maintenance of the embankment and culverts would be necessary to keep them operable.

MEDIA-SPECIFIC ACTION 1B: STABILIZE POND BERMS TO WITHSTAND FLOOD FLOWS LESS THAN A PROBABLE MAXIMUM FLOOD

This media-specific action would provide flood protection of the ponds for flood events that are less than a probable maximum flood.

As with Media-Specific Action 1A, there are three discrete actions included in Media-Specific Action 1B. These include:

- Raise the pond berms along the Mill-Willow Bypass to protect against the designated floods.
- Reconstruct the Mill-Willow Bypass, as necessary.
- Provide protection from the designated flood runoff from the eastern hills.

The components of Media-Specific Action 1B are shown in Figure 7-2 and are discussed in the following subsections.

Protect Pond Berms Along the Mill-Willow Bypass From Designated Floods

The pond berms along the Mill-Willow Bypass would have to be protected against overtopping or scour from certain

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designated floods. The Montana Department of Natural Resources and Conservation dam safety rules indicate that the appropriate requirements for flood protection are:

Pond No. 1	29,300 cfs (0.2 PMF)
Pond No. 2	44,000 cfs (0.3 PMF)
Pond No. 3	73,300 cfs (0.5 PMF)

A flood modeling program (HEC-2) was run to determine the flood depths at various places along the existing berm under the various flood scenarios. The model indicated the following:[8]

- The berms along Pond 1 are high enough to avoid overtopping by 0.2 PMF flows.
- The north half of the berm along Pond 2 is high enough to avoid overtopping by a 0.3 PMF. The south half of this berm would have to be raised by as much as 5 feet to avoid overtopping during a 0.3 PMF event.
- The northerly 3,500 feet of the Pond 3 berm would not have to be raised to protect against the 0.5 PMF flows. The remainder of the berm would have to be raised by as much as 8 feet to avoid overtopping during a 0.5 PMF event.

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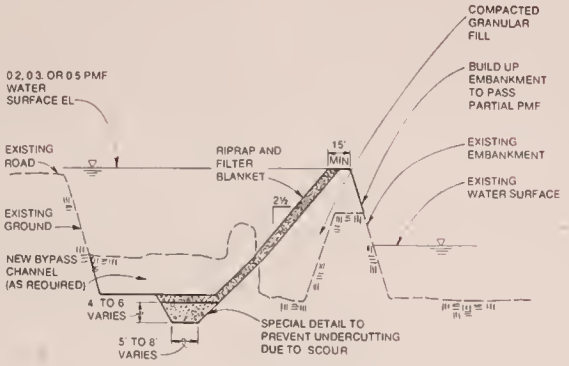
8 CH2M HILL, 1988.



MILL-WILLOW BYPASS AND EMBANKMENT
SECTION A-2
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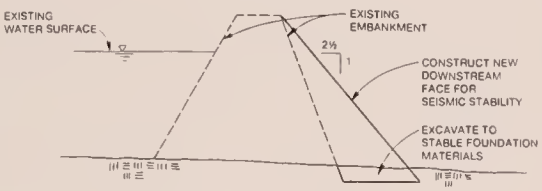

TYPICAL EMBANKMENT RECONSTRUCTION FOR SEISMIC STABILITY
SECTION C-2
NTS

FIGURE 7-2

PROPOSED CHANGES TO PROVIDE PARTIAL PMF AND EARTHQUAKE PROTECTION
MEDIA-SPECIFIC ACTIONS 1B & 3
WARM SPRINGS PONDS
FEASIBILITY STUDY

CH2M HILL

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- The outside of the berms would have to be protected against scour but to a lesser extent than for Media-Specific Action 1A. The lower flood heights and slower water velocities would require less riprap. The model predicted velocities ranging from 10 to 18 feet per second. Based upon these velocities, preliminary design of the riprap indicated that 5- to 150-pound rock would be required. Assuming dumped riprap, the required thickness would be 2 to 4 feet.[9] A filter blanket or geotextile mat between the riprap and the embankment materials would also be required.

Reconstruct the Mill-Willow Bypass, as Necessary

This would be similar to the reconstruction required by Media-Specific Action 1A. The magnitude of reconstruction, however, would be less than for Media-Specific Action 1A because the pond berms would not have to be raised as high. The concept would still be to reconstruct the bypass where the new slopes encroach upon the bypass. The reconstruction would be designed to provide no net decrease in flow capacity.

Flood Control Berm Along East Side of the Ponds

For Media-Specific Action 1-B, a flood control berm along the east side of the ponds is not required to protect the ponds from overtopping caused by floods in the eastern hills. The reason is that the designated floods can be contained

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[9] Caltrans, 1970.

within the existing storage volume of each of the ponds without modification. If the assumption is made that the flood volumes will be reduced by the same percentage as the flood peaks, the designated floods will result in a rise in water surface elevation in each pond (Table 7-3).

Table 7-3
WATER SURFACE RISE IN PONDS FROM FLOODS

Pond No.	Designated Flood Volume (ac-ft)[a]	Storage Available within Existing Berms (ac-ft)	Approximate Rise in Water Surface Elevation (ft)	Approximate Total Available Freeboard (ft)
Pond No. 1	440 (0.2 PMF)	2,000	1.6	7
Pond No. 2	900 (0.3 PMF)	1,700	1.9	4
Pond No. 3	500 (0.5 PMF)	3,000	0.7	5

[a]Flood volumes are based on the simplifying assumption that the volume generated can be reduced by the same percentage as the reduction in peak flow.

None of the designated flood volumes from the eastern hills should result in overtopping of the pond berms. It should be noted that capping or flooding of tailings in Ponds 1 and 2 to isolate the tailings would result in loss of some of the potential storage volume (see Media-Specific Actions 7 and 8 for details of capping and flooding options). Storage volume, especially in Pond 2, should be evaluated in greater detail during the design phase if either of these options is chosen for isolating the tailings in the ponds.

MEDIA-SPECIFIC ACTION 2:
STABILIZE/SOLIDIFY POND SEDIMENTS

As with Media-Specific Actions 1A, 1B, and 3, the primary objective of Media-Specific Action 2 is to protect against loss of the pond sediments during major flood or earthquake events. This would be accomplished through an in-place

stabilization/solidification treatment process that would immobilize the pond sediments. Additionally, this technology would reduce groundwater contamination caused by the leaching of contaminants from sediments. In situ stabilization/solidification is a relatively new technology in the U.S., although it has been used extensively in Japan. It is currently being adapted in the U.S. to neutralize and/or stabilize hazardous material in contaminated soil.

The descriptions and evaluations presented in this section are based on the Detoxifier™ process; however, other in situ mixing devices are available. The Detoxifier™ is a device that simultaneously homogenizes a waste and dispenses treatment agents into the waste; it would be capable of penetrating and mixing to the maximum depths of the existing pond bottom sediments. The following quotation is taken directly from vendor literature describing the device and its use:

> It consists of an assembly of two cutter/mixer bits connected to separate, hollow kelly bars. The bits overlap and rotate in opposite directions, creating a mixing area of approximately 40 square feet. The rotating action provides for simultaneous cutting, mixing, homogenizing, and pulverizing of the soil/waste material. Treatment agents can be conveyed through the hollow kelly bars and ejected through feed jets to the mixing area. A rectangular shroud covers the mixing area to minimize dust generation. Computer monitor sensors are used to determine and adjust penetration depth, augering rates, and chemical feed rates.

Ponds 2 and 3 would have to be drained slowly over the course of the stabilization/solidification process. The mixing units would be barge-mounted and the solidification

would be done at the water's edge, with the deepest areas of the ponds being stabilized/solidified last. If Pond 1 were stabilized, the mixing units would likely be track-mounted because the majority of Pond 1 is already drained and able to support the equipment.

Three phases of work would be required for in situ stabilization/solidification of pond bottom sediments. In Phase 1, chemicals would be mixed with the sediments to immobilize metals. Phase 1 would be accomplished in two steps: first, an acidified ferrous sulfate solution would be mixed into the sediments to precipitate metals; and second, calcium hydroxide would be blended with the sediments to raise the pH. In Phase 2, a 5 percent pozzolonic cement would be added to solidify the sediments. In Phase 3, a vegetated soil cover would be placed over the site upon completion of the stabilization/solidification operations and appropriate site grading and preparation.

Each Detoxifier™ could process pond bottom sediments at a rate of up to 50 cubic yards per hour. Assuming that four Detoxifiers™ were used for 24 hours a day, 6 days a week, it would take approximately 14 years to solidify the 19 million cubic yards of sediments in Ponds 1, 2, and 3. Actual time and reagent requirements would need to be determined by pilot tests during the design phase.

The reliability of current technology for in situ stabilization of metals in soil is not well proven. Several full-scale prototype projects have been attempted in the United States, with varying degrees of success. Verification of complete mixing and stabilization is difficult for any in situ operation.

For these reasons, bench-scale and pilot treatability studies would be required during the design phase to determine if the technology can be used on the pond bottom sediments and meet the remedial action treatment objectives (see Chapter 5). The design-phase studies would also determine more precisely the amounts and types of reagents, and the sequencing and mixing times necessary to ensure satisfactory stabilization and solidification.

This media-specific action would also include solidification of all the tailings deposits and contaminated soils after they were excavated and moved to one of the ponds. The excavation and movement of the tailings deposits and contaminated soils is addressed under Media-Specific Action 10.

As noted previously, in situ stabilization/solidification would make the existing treatment ponds no longer usable for treating the contaminated flows in the creeks. A new pond would have to be constructed to continue to provide metals removal for the Mill, Willow, Silver Bow Creeks system, at least until the upstream sources of the contaminants are controlled or removed. This new pond is addressed in Media-Specific Action 5C.

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MEDIA-SPECIFIC ACTION 3: STABILIZE POND BERMS TO WITHSTAND A MAXIMUM CREDIBLE EARTHQUAKE

Preliminary geotechnical investigations indicate that the existing dikes containing the ponds would be unstable in

many locations during a major seismic event.[10] From existing embankment cross section and seismic data,[11] a conceptual level stability analysis was performed on the pond dikes to determine what corrective measures would be suitable for stabilizing them. That analysis indicated that the dike crest would have to be widened and the downstream slopes of the dikes would have to be flattened to approximately a 2.5:1 slope to provide a factor of safety greater than 1.0 during a maximum credible earthquake.

The embankment cross sections indicate the dikes appear to be founded on a medium-dense to dense alluvial sand and gravel deposit. However, since construction of the dikes, the downstream toes of the dikes have been covered with loose sediments and tailings, particularly the downstream toes of the dikes for Ponds 2 and 3. The construction of the 2.5:1 downstream slope would, therefore, require the removal of the soft sediments until dense foundation materials are reached. In the development of this media-specific action for the pond bottom sediments, the downstream toe was assumed to be excavated to dense foundation materials and the downstream slope reconstructed at a 2.5:1 slope using an imported, free-draining granular material.

Most of the western dikes paralleling the Mill-Willow Bypass would have to be raised as part of the flood prevention measures to protect against floods (see Media-Specific Action 1A and Media-Specific Action 1B). The raising of the dikes would be made with 2.5:1 downstream slopes to satisfy the

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10 IECO, 1981.

11 Ibid.

seismic stability requirements. In those areas where the western dikes do not need to be raised for flood protection, the downstream slopes would be flattened to 2.5:1 for seismic stability.

Additional studies will have to be conducted during the design phase to more accurately define the dike geometry, the embankment properties, and the characteristics of the maximum credible earthquake.

The upstream slopes of the existing dikes were not evaluated in this feasibility study because no data were available that described the geometry and construction of the upstream slope or the depth and nature of the tailings covering the upstream slopes. The stability of the upstream slopes, particularly during a maximum credible earthquake, should also be evaluated during the design phase. In addition, a site-specific seismic evaluation should be conducted during the design phase to determine the maximum credible earthquake and its corresponding site acceleration, and to determine the potential for seismically-created water waves.

MEDIA-SPECIFIC ACTION 4: REMOVE AND DISPOSE OF CONTAMINATED SURFACE SOILS FROM ALONG THE MILL-WILLOW BYPASS

Media-Specific Action 4 is developed to achieve compliance with Montana water quality standards currently violated by the formation of the soluble metal salts along the Mill-Willow Bypass that cause the fishkills, and to reduce the potential for human exposure to the surface contamination.

This would be accomplished by excavating and removing the contaminated tailings and soils along the bypass.

Approximately 76,000 cubic yards of tailings deposits and 130,000 cubic yards of contaminated soil would have to be removed. These tailing deposits and contaminated soils were identified and mapped as part of the Phase II RI Study.[12] Areas containing the tailings are shown in Figure ES-1.

Two options are being considered for disposal of the tailings and contaminated soils:

- Transportation to an offsite RCRA treatment, storage, and disposal facility (TSDF)
- Transportation to an onsite non-RCRA disposal facility (Pond 1, 2, or 3 prior to solidification or capping)

The two disposal options are discussed in detail under Media-Specific Actions 9 and 10.

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MEDIA-SPECIFIC ACTION 5: IMPROVE THE POND TREATMENT SYSTEM

Media-Specific Action 5 was developed to represent the various approaches that could be implemented to reduce the

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[12] CH2M HILL, 1989. Phase II Remedial Investigation Data Summary. Prepared for the State of Montana Department of Health and Environmental Sciences, Helena, Montana.

metals loads in surface water of the Mill-Willow Bypass at the compliance point.

Three different approaches were developed:

- Media-Specific Action 5A. This approach includes the complete range of techniques identified to improve the capacity and reliability of the existing treatment system. It would provide the greatest improvement, among the three approaches, in the quality of the water discharged to the Clark Fork River.

- Media-Specific Action 5B. This is a less comprehensive approach to improving the existing treatment system. It includes a subset of the techniques identified in Media-Specific Action 5A and was developed to provide a range of options. It would provide some improvement in the quality of the water discharged to the Clark Fork River but not as great an improvement as Media-Specific Action 5A.

- Media-Specific Action 5C. This approach was developed to address the need for continuing treatment if the existing pond system is taken out of service. As noted in Media-Specific Action 2, Pond 3 and Pond 2 would have to be taken out of service if the stabilization/solidification option is implemented. This would require development of an alternative means to continue to treat the flows in Mill, Willow, and Silver Bow Creeks. One alternative treatment method would be to construct a new pond. There is space available upstream

(south) of the wetted area of Pond 3 to develop a new treatment pond.

Each of these approaches is developed in detail in the following sections.

MEDIA-SPECIFIC ACTION 5A: OVERALL UPGRADE OF THE POND TREATMENT SYSTEM

Media-Specific Action 5A includes a broad range of measures to improve the treatment efficiency and capacity of the existing pond system. The goal of this media-specific action is to improve the efficiency and capacity (maximum allowable flow rate) of the treatment system, and to provide a more flexible system whose operation can be optimized in practice.

The design maximum flow rate for Pond 3 as part of this Media-Specific Action is set at 600 cfs.[13]

The envisioned modifications should, once operation is optimized, achieve compliance with ARARs for surface water on a consistent basis.[14] The measures to improve efficiency and capacity are:

- Divert Mill and Willow Creeks into Pond 3
- Modify the inlet structure to Pond 3

[13] This flow rate corresponds to the maximum flow rate calculated to prevent pond bottom scour at the existing outlet structures and through a 1,000-foot berm opening. It also represents the maximum flow to achieve an approximately 2-day retention time in the pond. During the design stage of remediation the maximum flow rate could be adjusted assuming scour and retention time effects are considered.

[14] Further discussion of ARARs compliance of this, and all the other media-specific actions, is provided in Chapter 8.

- Channelize Silver Bow Creek within the dry areas of Pond 3
- Improve the lime addition system
- Add a berm across Pond 3
- Construct a new effluent structure for Pond 3
- Remove Pond 2 from the treatment system

These measures are shown in Figure 7-3 and are discussed in detail in the following subsections.

Diversion of Mill and Willow Creeks Into Pond 3

Currently, only water from Silver Bow Creek is treated in the pond system. This is because, historically, Silver Bow Creek, which received mining and milling wastes until the mid-1970s, has contained higher metal loadings than either Mill or Willow Creeks. However, a review of recent data indicates that Mill and Willow Creek flows entering the Mill-Willow Bypass, while not as contaminated as Silver Bow Creek, have an average copper concentration of 31 ug/l, which is in exceedance of the chronic aquatic water quality standard for copper (12 ug/l).[15] Because this loading currently passes untreated through the operable unit (i.e., it does not flow through the ponds), the copper standards often are not met at the compliance point. Under average conditions, the untreated bypass flow makes up approximately 20 to 50 percent (on a mass-load basis) of the metals contamination flowing out of the operable unit into the Clark Fork

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15 CH2M HILL, 1989.

River. This is shown in Table 7-4. Consequently, to routinely meet the water quality standards for aquatic life and public health protection at the compliance point, it would be necessary to divert the flow from the Mill-Willow Bypass into Pond 3 for treatment.

Table 7-4
AVERAGE METALS LOADING IN THE MILL-WILLOW BYPASS

Location	Flow Rate (cfs)	Arsenic Conc. (ug/l)[a]	% L[b]	Cadmium Conc. (ug/l)	% L	Copper Conc. (ug/l)	% L	Lead Conc. (ug/l)	% L	Zinc Conc. (ug/l)	% L
Flow into the operable unit	27	26	34	0.1	3	31	6	1	3	45	4
At Pond 2 discharge	33	22	55	0.1	23	37	18	2	23	72	22
Chronic water quality standard[c]	--	--	--	1.1	--	12	--	3.2	--	110	--

[a]Concentration in ug/l
[b]Weight as percent of total loading
[c]At a hardness of 100 mg/l
Source: CH2M HILL, 1989.

A dike to direct the bypass flow into Silver Bow Creek would be built east of the freeway, upstream of the Pond 3 inlet structure, and would include a spillway and a fuse plug. It would divert flows from Mill and Willow Creeks into the Silver Bow Creek channel from which they would flow into Pond 3. The Mill-Willow Bypass would, under average flow conditions, be dry from the diversion point to the Pond 3 outlet.

Modify the Inlet Structure to Pond 3

Because the existing inlet structure to Pond 3 has no trashrack, it frequently plugs with trash, causing it to operate below its design capacity of 700 cfs. Plugging occurred at least twice in the time period 1985 to 1987. Trash plugging has caused premature failure of the system's fuse plug, allowing all of the flow from Silver Bow Creek to flow into the Mill-Willow Bypass without treatment until the fuse plug can be reconstructed.

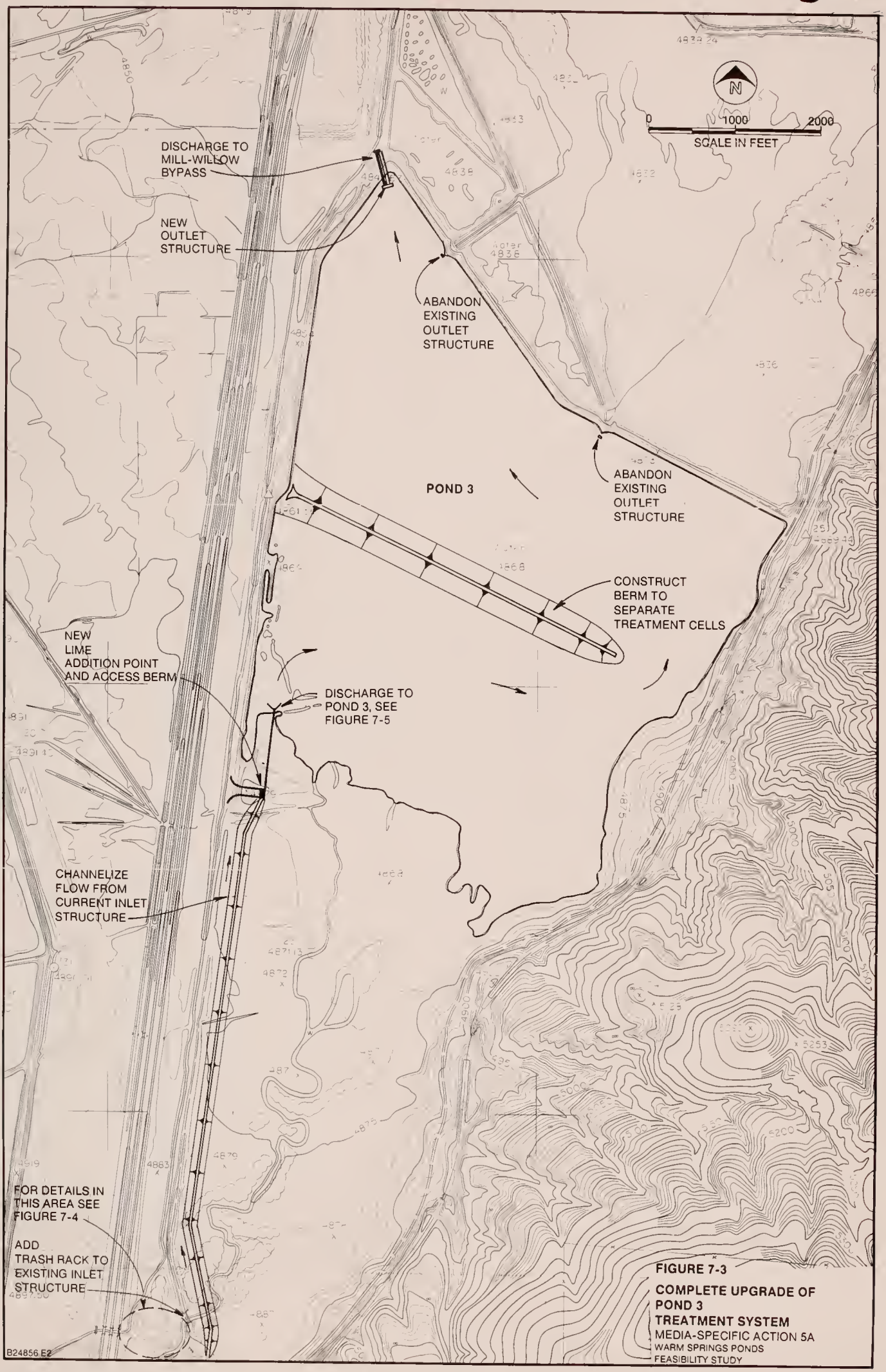


FIGURE 7-3

COMPLETE UPGRADE OF POND 3 TREATMENT SYSTEM

MEDIA-SPECIFIC ACTION 5A
WARM SPRINGS PONDS
FEASIBILITY STUDY

Several modifications would be made to the inlet structure to improve its hydraulic capacity and efficiency of operation:

- Addition of a Trashrack--A trashrack would be added upstream of the existing inlet structure. It would be constructed with wide spacing between the bars (4 to 6 inches). Also, it would be constructed at a relatively flat angle (no steeper than 45 degrees) to allow floating debris to ride up the trashrack and still allow flows through the rack. Maintenance would be necessary to keep the trashrack operating at full capacity.

- Addition of an Overflow Weir--A concrete overflow weir would be constructed to regulate flows. The maximum flow at which Pond 3 can provide effective treatment without the possibility of scour at the outlet structures is approximately 600 cfs, which is approximately a 2-year recurrence interval flood. During flows up to 600 cfs, the overflow weir would direct water through the trashrack and into Pond 3. If flows exceed 600 cfs, or if the trashrack becomes plugged, the excess would spill over the overflow weir and continue down the Mill-Willow Bypass. The weir would be approximately 350 feet long and would be designed to pass up to the 100-year flood in Silver Bow, Mill, and Willow Creeks (4,900 cfs).[16]

- Relocation of the Fuse Plug--The fuse plug would be relocated to the west end of the overflow weir

[16] The 100-year flood on Silver Bow Creek alone is 4,000 cfs. The 100-year flood for the combined flows of Mill, Willow, and Silver Bow Creeks is 4,900 cfs.

and designed to wash out if the combined Silver Bow, Mill, and Willow flows exceed the 100-year event (4,900 cfs).

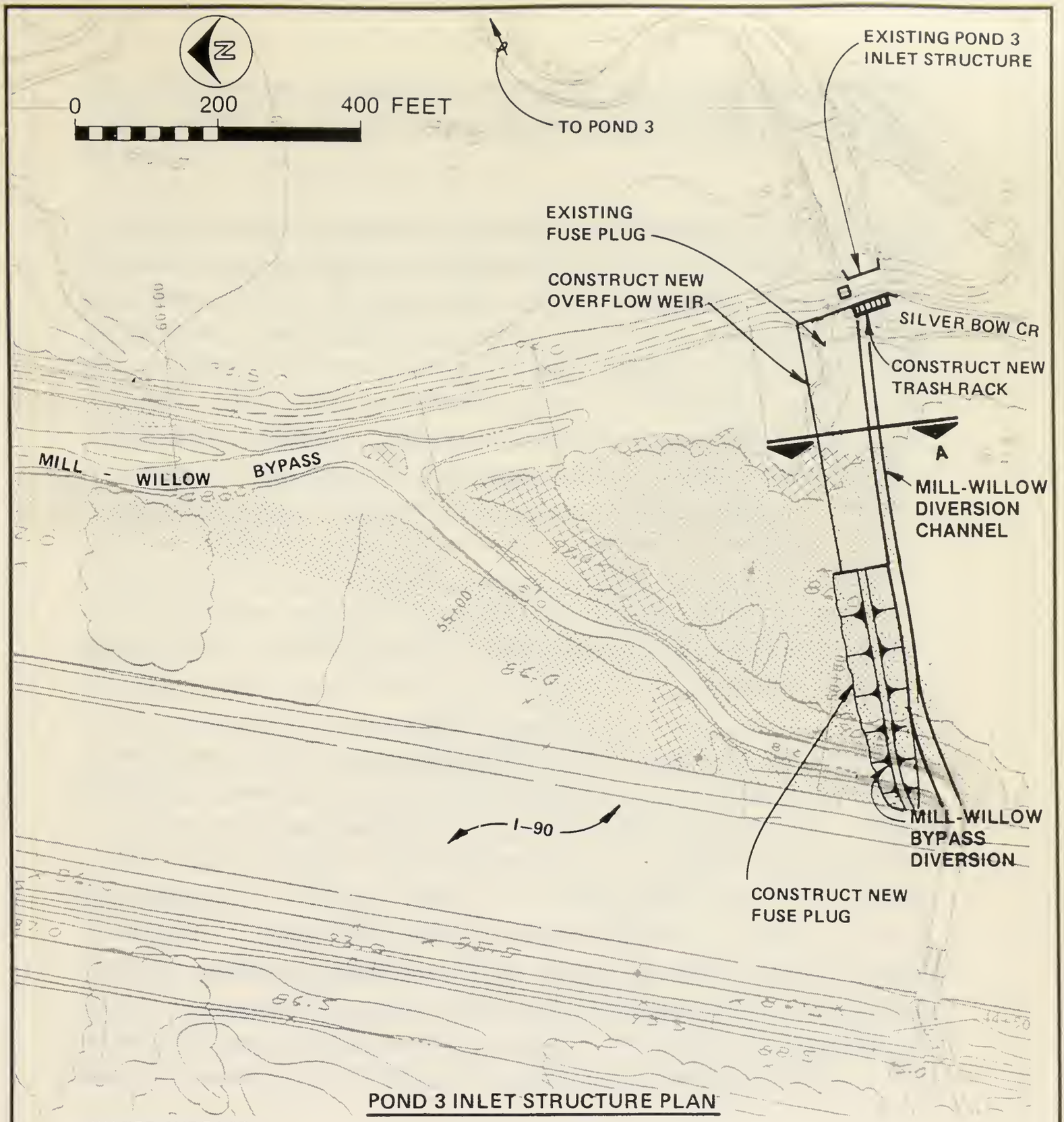
These modifications to the inlet structure are shown in Figure 7-4.

Channelization of Silver Bow Creek

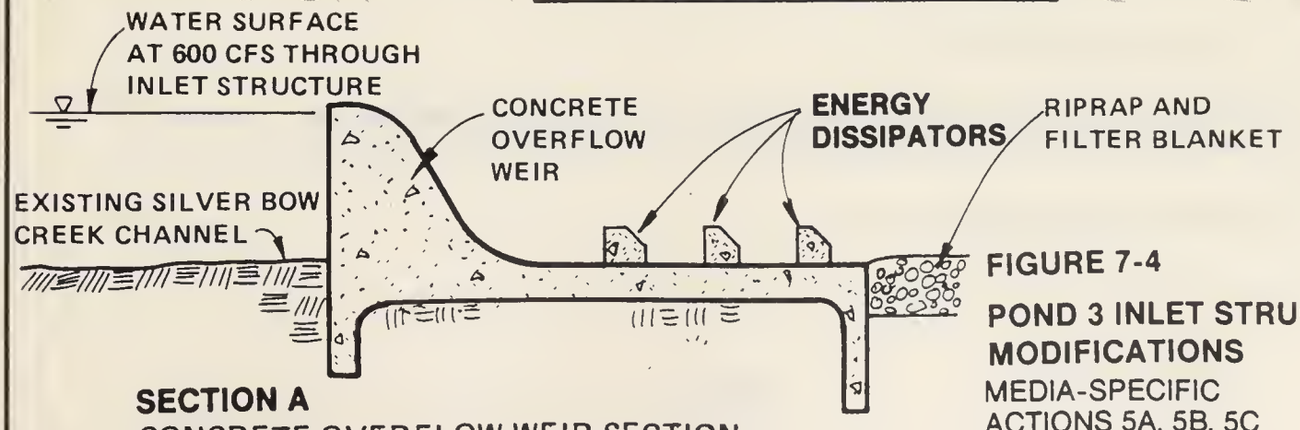
Influent to Pond 3 passes through the inlet structure approximately 8,000 feet (1-1/2 miles) upstream of the pond water surface. Flow from the inlet structure to the pond currently follows a natural channel through deposited tailings. To better control the direction of the flow and to limit interaction with tailings deposits, the flow would be channelized in a riprap-lined earthen channel from the inlet structure to the lime addition facility. Downstream from the lime addition facility, the channel would be concrete lined to minimize lime sludge deposition. The old channel would be abandoned and the new channel would parallel the existing western berm of Pond 3. The new channel would have a maximum design capacity of approximately 600 cfs--a 2-year recurrence interval flood. The new channel is shown in Figure 7-3.

Improve the Lime Addition System

Metals removal in Pond 3 occurs through three separate and distinctly different actions: the formation and precipitation of metals hydroxides under alkaline conditions; biological processes including uptake, complexation, and calcite coprecipitation; and the settling of suspended solids under quiescent conditions. Unlike most typical treatment



POND 3 INLET STRUCTURE PLAN



SECTION A
CONCRETE OVERFLOW WEIR SECTION
NTS

FIGURE 7-4

POND 3 INLET STRUCTURE MODIFICATIONS
MEDIA-SPECIFIC
ACTIONS 5A, 5B, 5C
WARM SPRINGS PONDS
FEASIBILITY STUDY

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systems, which rely on only one of these processes, the existing pond system uses all three processes to remove the metals.

For effective formation and precipitation of metal hydroxides to take place, pH values greater than 8.5 are typically necessary in treatment ponds. The high pH values result in precipitation of dissolved metals as hydroxides. During the late spring and through summer (June through September), the pH in Pond 3 appears to cycle between 8 and 9.5.[17] This is apparently due to natural biological activity, and lime addition frequently is not necessary during this period. However, during the winter months, the pH of the influent typically drops to below 8. For adequate treatment to occur between October and May, lime would be added to the pond influent to raise the pH in the system. Lime would also be added from June through September, as necessary, to maintain a pH of around 9.

A target pH of 9 was selected based on data obtained from laboratory treatability studies conducted on Pond 3 influent water, and because it represents the upper aquatic water quality standard for pH. Treatability data were also obtained for lime treatment of influent water to pH levels of 8.5, 10, and 11, and for lime-sulfide treatment of influent water at pH levels of 9 and 11.[18] If metal removal rates are found to be insufficient using lime addition to a pH of 9, the use of additional lime or lime-sulfide would be possible. If it becomes necessary to operate at pH levels higher

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17 MultiTech, 1987. Silver Bow Creek Remedial Investigation Final Report. Submitted to Montana Department of Health and Environmental Sciences, Helena, Montana.

18 For results, see CH2M HILL, 1989.

than 9, it may be necessary to provide pH adjustment prior to discharge. The need for pH adjustment will be studied during the design phase.

The biological processes important in reducing metals concentrations in the pond system were not studied in detail during the remedial investigation. But, based on established understanding of how metals treatment ponds typically work, they likely include bio-uptake and calcite coprecipitation. Both of these processes, while varying in their degrees of importance, would result in a further reduction of metals concentrations in the pond system beyond that provided by metal hydroxide precipitation due to elevated pH.

Copper and zinc are both micronutrients required by virtually all of the plant and animal life in the ponds.[19] Some uptake is, therefore, necessary and can be expected. However, the amount of the trace metals needed by the pond life is typically very small compared to the average concentrations in the treatment ponds, and increasing the concentrations of micronutrients is not thought to have any bearing on actual metabolic requirements.[20] Consequently, bio-uptake is not expected to be a major sink for the metals in the ponds.

Calcite coprecipitation is more likely to be a major driving force for metals removal during the summer months. Littoral flora and phytoplankton utilization of CO_2 in the photosynthesis process in the pond results in the formation of

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19 Wetzel, R.G., 1983. Limnology. 2nd Edition, CBS College Publishing, San Francisco, California.

20 Ibid.

carbonate (CO_3^{2-}).[21] Because of the high bioactivity noted in the pond during the spring and summer, this process would result in the formation of large quantities of carbonate in Pond 3. Since the solubility of carbonate compounds is typically low, the carbonate rapidly complexes with available calcium and other metals and precipitates. While calcium is the most typical element complexed and precipitated, the large concentrations of copper and zinc in the ponds would also be precipitated.

This process also results in the diurnal pH shift seen in the ponds. The pH in the ponds rises during the day due to photosynthetic use of CO_2 (a weak acid) and the formation of CO_3^{2-} (a strong base). At night, the reverse process occurs as photosynthesis slows and respiration (a CO_2-producing process) becomes primary. Consequently, metals precipitated during the day would be somewhat redissolved during the night. However, because the pond system appears to be a well-buffered, hard water system,[22] the amount of metal carbonates precipitated during the day should far exceed the amount resuspended during the night with the system acting as a carbonate-precipitation, metal sink.

Effective settling of the metal hydroxides, dead algae, metal carbonates, and suspended solids requires quiescent conditions in the pond and sufficient settling time. Typical detention times in metals treatment ponds tend to be between 2 and 25 days.[23] Calculated detention times for

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21 Wetzel, 1983.

22 MultiTech, 1987.

23 Metcalf and Eddy, 1979. Wastewater Engineering: Treatment, Disposal, Reuse. McGraw-Hill, New York, New York.

Pond 3 fall within this range. The detention time for average design flow (Mill, Willow, and Silver Bow Creeks combined: 100 cfs) is 20 days, and for maximum flow (600 cfs) is 3 days. The formation of calcite coprecipitates is probably also enhanced by quiescent conditions but can occur in algal mats under flowing or slowly moving water.

The settling of metal hydroxides, calcite coprecipitates, and suspended solids in Pond 3 results in the formation of sludges in the pond. The hydroxide sludge generation rate was measured during the treatability studies (Phase II RI Report, 1989) using Pond 3 influent. Treatment of the Pond 3 influent to a pH of 9 in the laboratory resulted in the formation of approximately 0.66 ml of sludge per liter of water treated. Assuming lime treatment for two-thirds of the year at an average flow rate of 100 cfs, roughly 47,000 cubic yards of hydroxide sludge would be generated each year. Sludge generation rates for the other sludge-producing processes were estimated using influent and effluent concentrations and typical biodeposition rates. The estimated contribution of these other processes to sludge generation rates is less than 2,000 cubic yards per year.

Assuming that a 3-foot average minimum depth would be needed in Pond 3 to provide adequate treatment, the total volume available for sludge storage would be roughly 4 million cubic yards. Accordingly, using these calculations, Pond 3 would fill with hydroxide sludge (to a 3-foot average depth) in approximately 80 years. As the pond filled to near this depth, the maximum flow allowed through the pond would have to be decreased. The significance of the useful life of Pond 3 is discussed further in Chapter 8 as part of the

detailed analyses.[24] The same calculations done for treatment using lime addition to a pH of 11, which generates a substantially greater quantity of sludge, indicate that the pond would fill in less than 10 years. Once Pond 3 is filled with sludge, a new treatment pond would be needed if the flows in Mill, Willow, and/or Silver Bow Creeks still required treatment. Media-Specific Action 5C discusses development of a new pond.

Lime addition would take place along the lined channel, approximately 2,000 feet from the discharge into Pond 3, as shown in Figure 7-3. Following the addition of lime to the system, the influent would flow the final distance to Pond 3 in a channel designed to maintain flow velocity above 2 feet per second. This would allow for a 10- to 15-minute mixing and dissolution period at average design flows before the water enters the pond. This period would provide additional mixing and help to prevent settling of lime and/or metal hydroxides in the channel above the pond. The lime addition structure would be designed to provide an initial rapid mix of the influent immediately after the addition of the lime to ensure complete mixing.

Lime would be fed to the pond system influent using a continuous feed lime slaking system. Conceptually, the system would consist of a cylindrical lime storage silo with a conical-shaped bottom, a gravimetric lime metering unit, and a detention-type lime slaker. In the slaking process, quicklime is mixed with water in a predetermined ratio to produce a lime paste or slurry. The slurry is detained in the slaker, during which time grit is removed. The slurry is diluted further to the desired concentration and is then

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[24] MultiTech, 1987.

released into the receiving stream. To provide a factor of safety in the case of system breakdown and to allow lime addition to continue during maintenance, a 100 percent redundant lime addition system is assumed in this feasibility study. Final process design and equipment selection would be performed during the design phase.

The lime is expected to be delivered to the site via tanker truck. The infrastructure to the lime addition point would require upgrading to allow for adequate lime delivery.

Following lime addition, the water would enter the wet portion of Pond 3 through a discharge structure. The structure would be designed to spread and slow the water carried in the channel as it reaches Pond 3. At average design flow, the structure will slow the velocity of the water as it enters Pond 3 to less than 0.5 feet per second to minimize scour. A conceptual design of the structure is shown in Figure 7-5.

Berm Across Pond 3

The settling characteristics in Pond 3 could be improved by adding a berm across the pond in a northwestern to southeastern direction, parallel to the eastern part of the northern berm (see Figure 7-3). This would effectively split the pond into two treatment cells, thus increasing the amount of the pond used for treatment and helping to prevent short-circuiting. The berm would also reduce the open surface area of the pond, thereby reducing wind effects on the pond's water and sediment. The berm, which would be built with approximately 2.5:1 sideslopes, would rise approximately 4 to 5 feet above the water level in the pond. It

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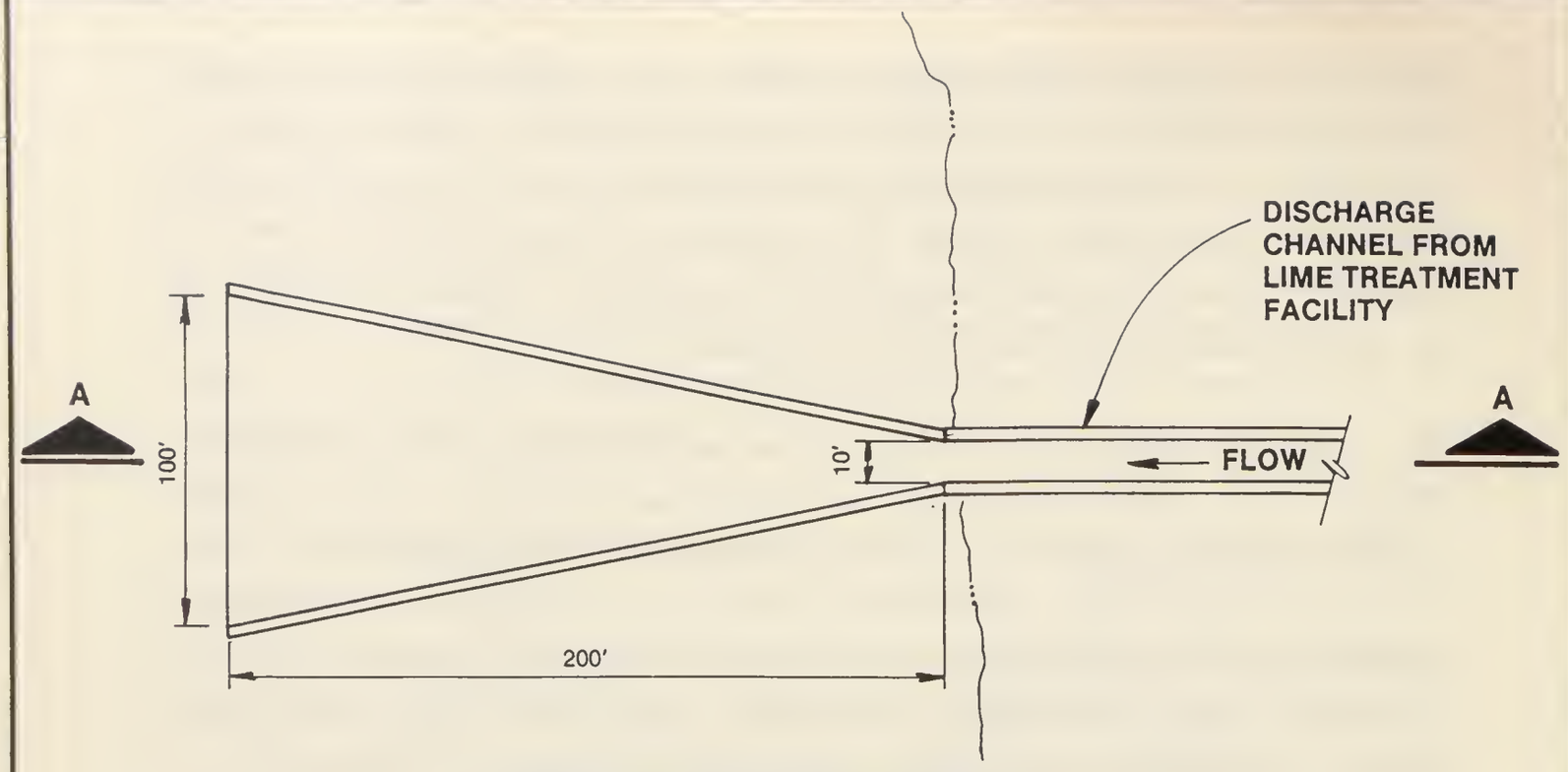

DISCHARGE STRUCTURE PLAN
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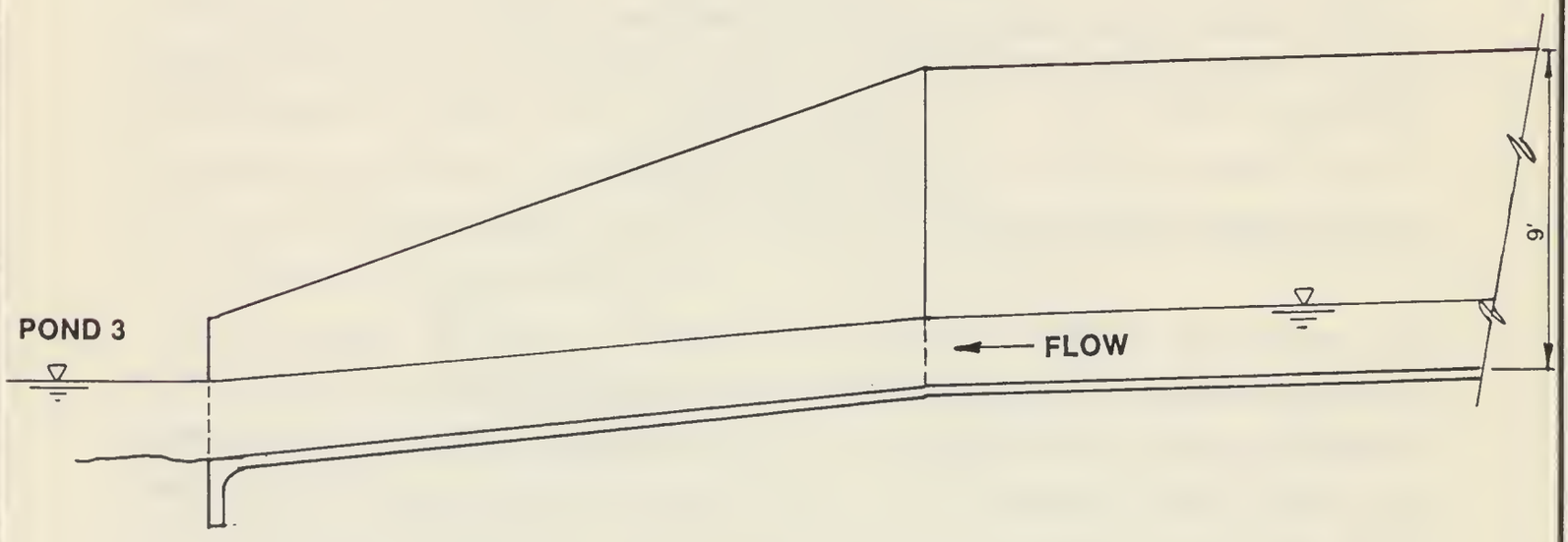

SECTION A
NTS

FIGURE 7-5

CONCEPTUAL DISCHARGE STRUCTURE TO POND 3
MEDIA-SPECIFIC ACTION 5A
WARM SPRINGS PONDS
FEASIBILITY STUDY

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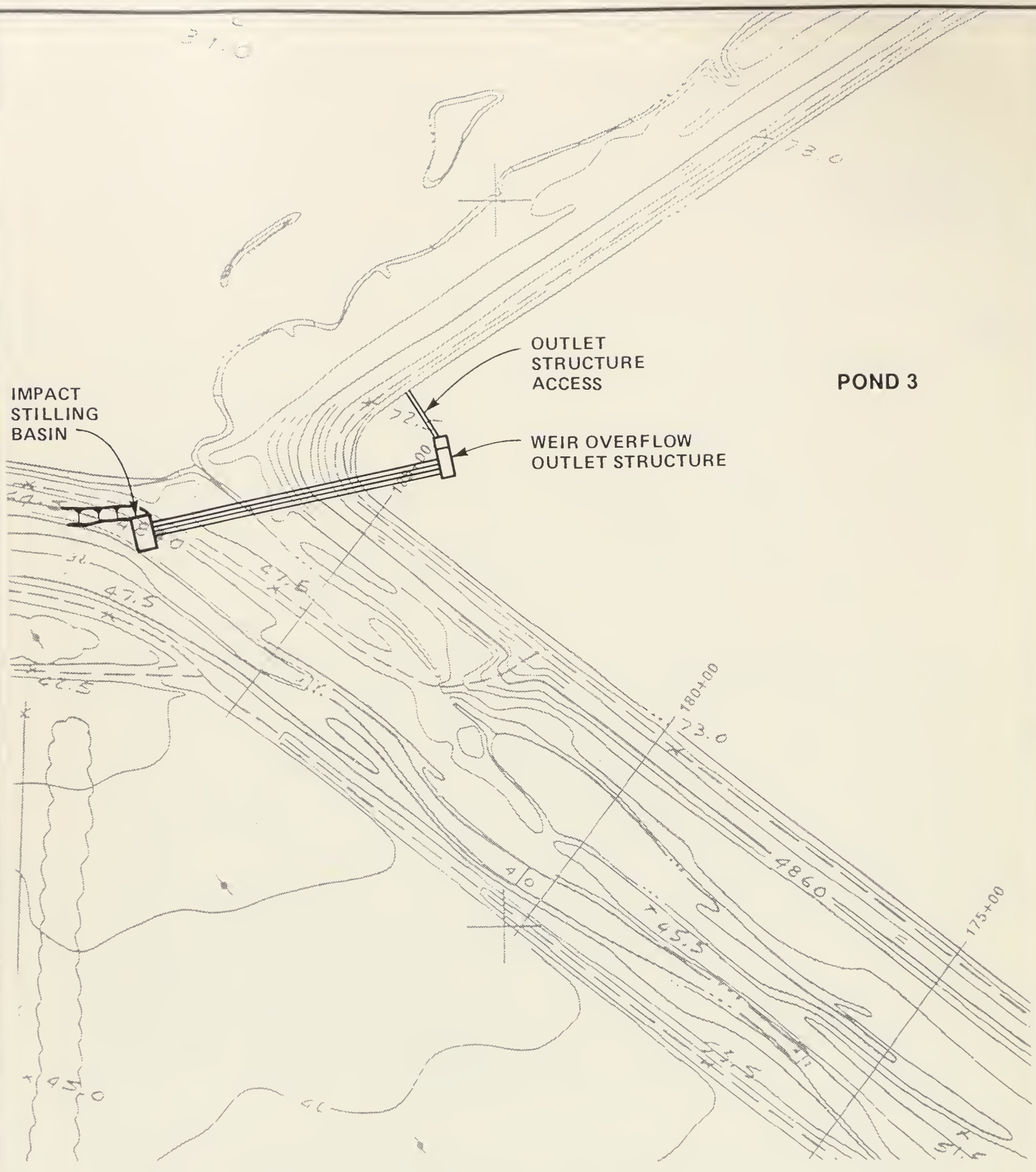
would stop approximately 1,000 feet from the eastern edge of the pond to provide a channel for flow around the berm. The channel is sized to promote nonturbulent flow around the berm to limit the disturbance of settled sludge in the area of the constriction.

Improved Effluent Structure

Effluent would be discharged from Pond 3 from one primary and several secondary locations. The main discharge would be from a new effluent structure constructed at the northwestern corner of the pond. Secondary discharges would flow into the wildlife ponds and provide minimum flow into Pond 2 to maintain water levels and avoid stagnation. The two current discharge structures would no longer be used.

The new outlet structure would allow discharge directly from Pond 3 to the Mill-Willow Bypass. (Pond 2 would no longer be used for treatment; see discussion below.) The discharge point would be located out in the pond to minimize approach velocities and sediment scour. It would have approximately 150 linear feet of effective weir length and would utilize downward opening weir gates for ease of operation. Its proposed location is shown in Figure 7-6. A conceptual design for such a structure is presented in Figures 7-7 and 7-8. The flow would be directed to the bypass through a series of reinforced concrete pipes to be constructed beneath the western berm. The structure would discharge through energy dissipation structures into the bypass.

Temporary cofferdams would be constructed in Pond 3 to facilitate construction of the outlet structure. They would be constructed by pushing gravels out into the pond from one



SCALE: 1" = 200'

FIGURE 7-6

WEIR OVERFLOW OUTLET STRUCTURE SITE PLAN

MEDIA-SPECIFIC ACTION 5A

WARM SPRINGS PONDS FEASIBILITY STUDY

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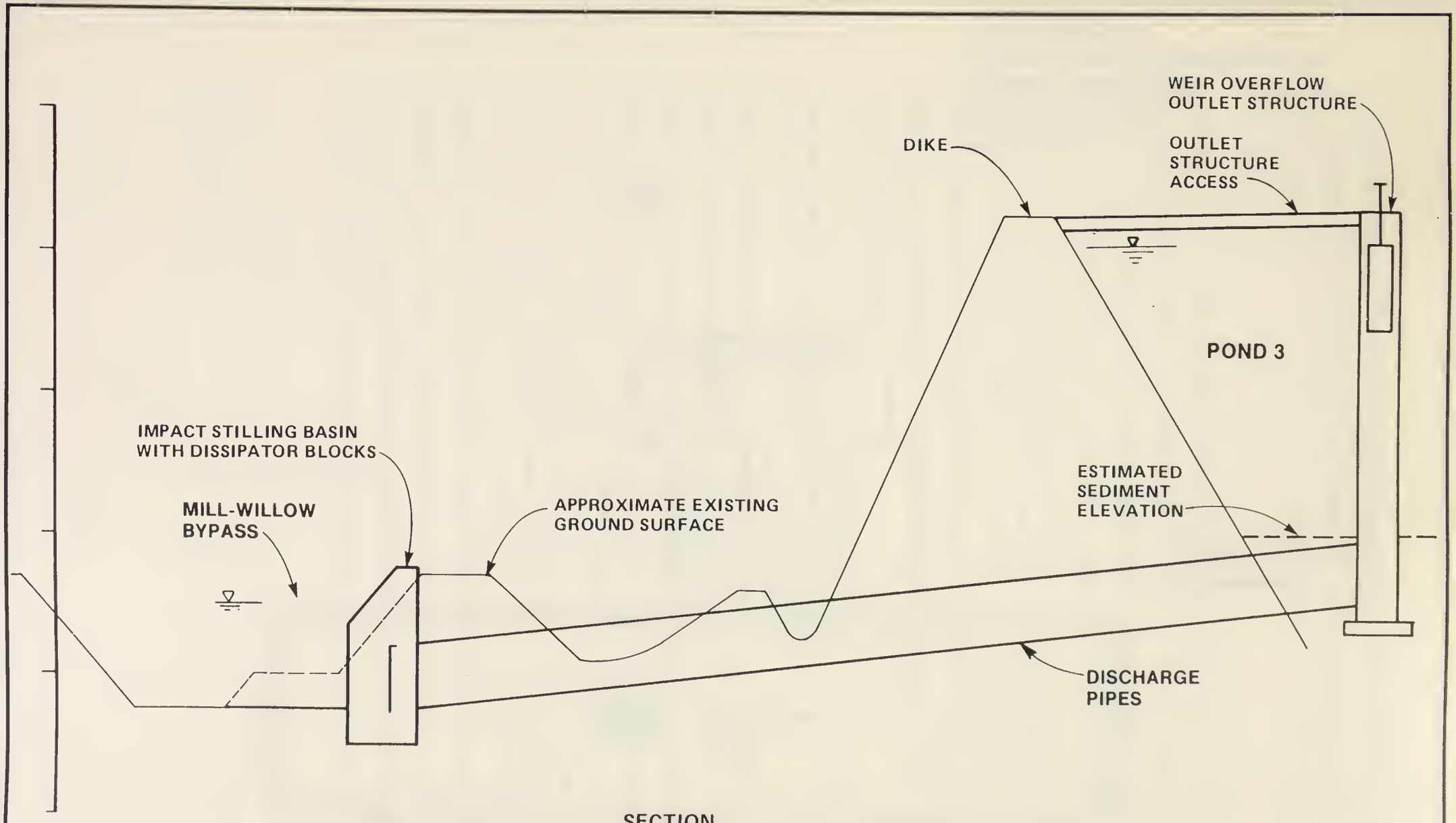

SECTION
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FIGURE 7-7

WEIR OVERFLOW
OUTLET WORKS

MEDIA-SPECIFIC ACTIONS 5A AND 5C
WARM SPRINGS PONDS
FEASIBILITY STUDY

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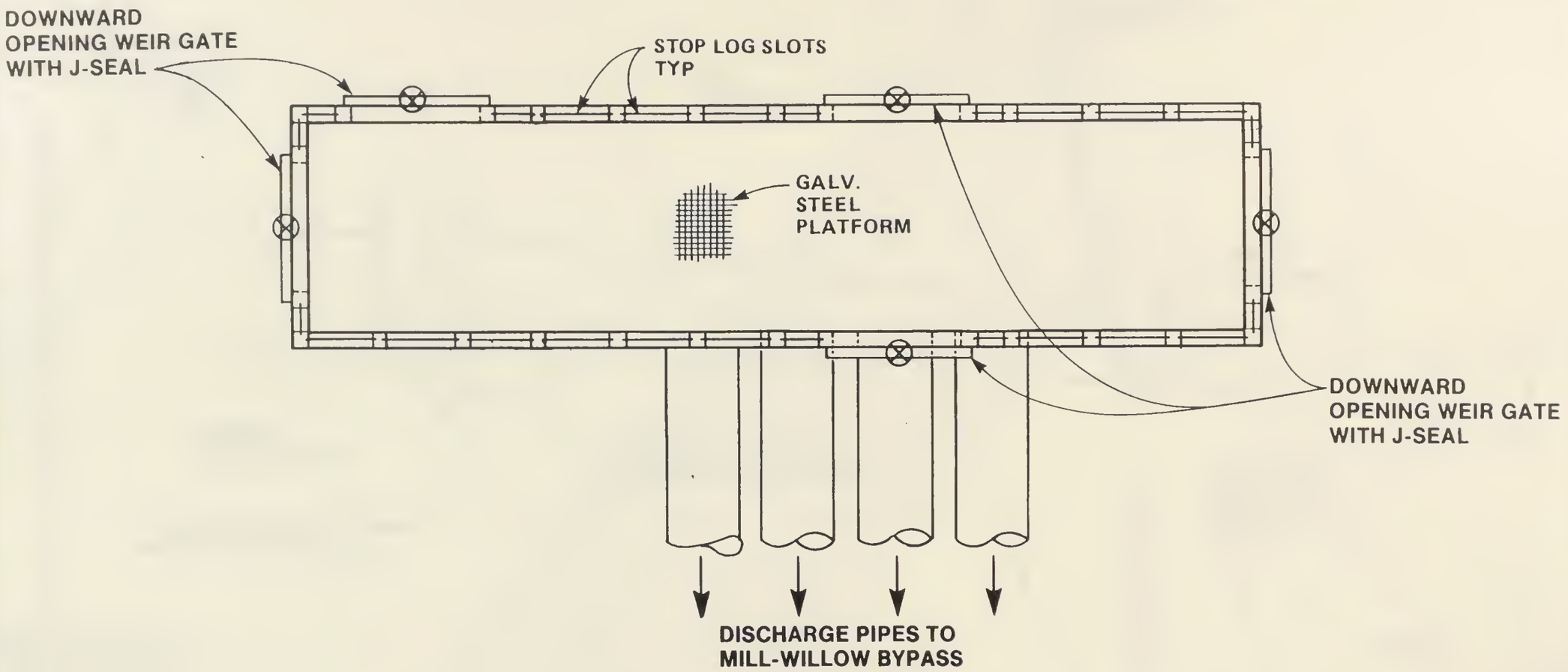

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FIGURE 7-8

WEIR OVERFLOW
OUTLET STRUCTURE
MEDIA-SPECIFIC ACTIONS 5A AND 5C
WARM SPRINGS PONDS
FEASIBILITY STUDY

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of the berms. The cofferdams would likely require clamshell or dragline excavators for removal. The removed cofferdam materials could be used in construction of the berm across the pond.

A fraction of the effluent would be discharged to the existing wildlife ponds in a continuation of the current practice. This water, which is used to maintain a minimal flow through the wildlife ponds, is currently fed to the wildlife ponds through siphons that carry it from Pond 3 over the Pond 3 berm and into the respective ponds. A buried pipe system would replace the siphons to provide more reliable operation, especially during the winter. Water would flow from Pond 3, as necessary, to maintain the current flow through the wildlife ponds.

Remove Pond 2 from the Treatment System

Pond 2, which currently receives most of the flow from Pond 3, would no longer be used as part of this alternative. Based on a review of pond bottom elevations, the average depth of Pond 2 is less than 2 feet.[25] Only at the exit to the pond does the water depth exceed 5 feet. Consequently, it can be assumed that most of the sludge storage capacity of the pond has been exhausted. In addition, the calculated detention time in Pond 2 for average flows is 3 days, much less than the time typically necessary for adequate settling. The lack of sludge capacity and adequate detention time is evident during periods of high flow when effluent metals concentrations have been found to be greater

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25 CH2M HILL, 1989.

than the concentrations in the influent. Thus, the shallow depth of Pond 2 limits the maximum flow that can be routed through the system as currently configured.

Because Pond 2 would no longer be used to provide treatment, the two effluent discharge structures from Pond 3 that currently feed Pond 2 would be removed from service. A limited amount of water from Pond 3 would be continuously discharged into Pond 2 in order to maintain the current water level of the pond and prevent salt buildup in the pond. A buried pipe discharge system would be installed to discharge the water from Pond 3 to Pond 2. The small flow of water from Pond 2 would be discharged directly into the Mill-Willow Bypass.

MEDIA-SPECIFIC ACTION 5B: LESS COMPREHENSIVE UPGRADE OF THE POND TREATMENT SYSTEM

Media-Specific Action 5B would be similar to Media-Specific Action 5A in that it would improve the overall treatment of the Pond 3 system. It would be a scaled-back version of Media-Specific Action 5A and would incorporate only the following elements:

- Divert Mill and Willow Creeks into Pond 3
- Modify the inlet structure to Pond 3
- Improve the lime addition system

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- Retain existing effluent structures and keep Pond 2 in service

Each of these items is discussed below.

Divert Mill and Willow Creeks into Pond 3

This element would be identical to the improvements discussed in Media-Specific Action 5A.

Modify Inlet Structure to Pond 3

The modifications to the inlet structure would be as discussed in Media-Specific Action 5A, with the exception that the inlet structure would be designed to limit flows into the pond system to less than 210 cfs so that Pond 2 could continue to function as a viable treatment pond. The maximum flow rate of 210 cfs was chosen based upon the minimum criterion for effective metals-removal in a pond system. As noted in Media-Specific Action 5A, the normal detention criterion for sizing metals-removal ponds is 2 to 25 days. At the minimum detention time of 2 days, the maximum flow rate through Pond 2 would be 210 cfs.

Improve the Lime Addition System

The improvements to the lime addition system would be similar to those presented in Media-Specific Action 5A. A new lime feeding and mixing facility would be constructed similar to Media-Specific Action 5A, except that it would be downsized to meet the requirements of the lower maximum flow through the pond system. The lime addition system would be located at or near the existing inlet structure. It would

feed lime into the water at that point, then allow the flows to follow the natural channel through the south portion of Pond 3.

Retain the Existing Effluent Structures and Keep Pond 2 in Service

Rather than construct a new effluent structure in Pond 3, the existing structures would remain in service. Since the existing structures discharge to Pond 2, this option would require that Pond 2 remain in service.

This less comprehensive alternative would provide some improvement to the treatment in the pond system, especially for flows no higher than 210 cfs. The modified inlet structure and lime addition system would allow more consistent diversion of flows near the average flow into the pond and more consistent chemical augmentation of the biological processes in the pond during the winter. Diversion of Mill and Willow Creek flows into the pond system would improve the quality of the water at the compliance point.

This media-specific action would not decrease the potential for short-circuiting in Pond 3 and therefore would not improve the efficiency of Pond 3 as a treatment pond.

Pond 2 would continue to be a source of suspended metal contaminants at the compliance point during high wind conditions that cause waves and re-entrainment of the sediments in the shallower areas of the pond.

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MEDIA-SPECIFIC ACTION 5C: CONSTRUCT A NEW TREATMENT POND

The construction of a new pond treatment system would be required in conjunction with stabilization/solidification of the existing pond bottom sediments (see Media-Specific Action 2). To provide continuous treatment, the new treatment pond would have to be constructed before the existing ponds could be dewatered.

A new treatment pond could provide an effective means of treating the flows from Mill, Willow, and Silver Bow Creeks. A reduction in metals concentrations at the compliance point, compared to current levels, would be achieved through the improved treatment that a new pond would provide. The discussion of improved treatment included in Media-Specific Action 5A is equally relevant to the new pond envisioned for this media-specific action because the new pond would have basically the same design features and capacity limit (approximately 600 cfs). The new pond would not be expected to be as effective as Pond 3 if the latter were fully upgraded (Media-Specific Action 5A) because the new pond could be no larger than approximately 70 percent of the volume of Pond 3. At 600 cfs the new pond would have a retention time of just under 2 days, considered to be the minimum for adequate settling. The reduced retention time, due to its smaller size, would make it less efficient as a treatment pond. An overview of the measures taken to improve treatment is presented in Figure 7-9.

The new pond would be located within the existing Pond 3 berms, upstream (south) of the current Pond 3 water surface. Pond 3 and the new pond would be separated by a 31-foot-high berm. Flows up to approximately 600 cfs would enter the new pond treatment system through a revised inlet structure as detailed in Media-Specific Action 5A (Figure 7-4). A lime

addition system, as described in Media-Specific Action 5B (except that it would be sized for 600 cfs flows), would be located at the pond inlet structure. Pond effluent would be discharged to the Mill-Willow Bypass through an outlet structure and located at the northwest corner of the new pond and similar to that shown in Figures 7-6, 7-7, and 7-8.

The settling characteristics in the new pond treatment system could be improved by including a berm across the pond in a northwestern to southeastern direction, parallel to the eastern part of the northern berm (Figure 7-9). This berm would be constructed similar to the berm detailed in Media-Specific Action 5A.

MEDIA-SPECIFIC ACTION 6: CONSTRUCT AN UPSTREAM FLOOD IMPOUNDMENT/SETTLING BASIN

Media-Specific Action 6 was developed to address the surface water contamination caused by higher flow rates in Silver Bow Creek that tend to erode tailings and contaminated soils upstream of the ponds and transport them through the operable unit to the Clark Fork River. As noted in previous media-specific actions, the maximum flow rate into the pond system proposed under any of the treatment options is 600 cfs. Mill-Willow-Silver Bow flows in excess of 600 cfs (approximately a 2-year recurrence interval flood) would be bypassed by the upgraded inlet structure and allowed to flow untreated down the Mill- Willow Bypass. Two options were developed under Media-Specific Action 6 to address dealing with flows in excess of 600 cfs:

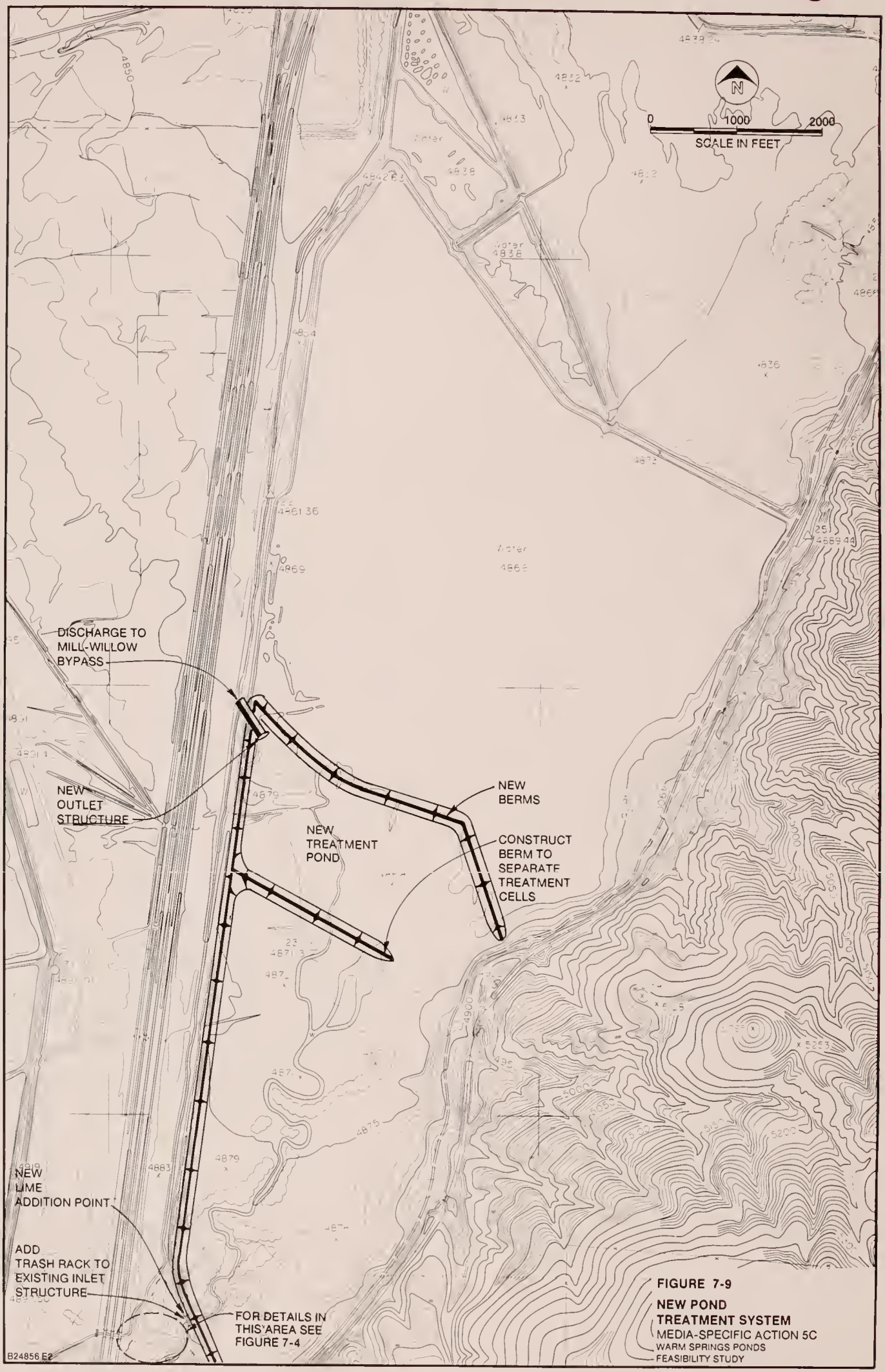

FIGURE 7-9

NEW POND TREATMENT SYSTEM

MEDIA-SPECIFIC ACTION 5C

WARM SPRINGS PONDS

FEASIBILITY STUDY

- Media-Specific Action 6A. This option would provide settling and treatment for up to the total runoff volume of the 100-year event in Silver Bow Creek (13,000 acre-feet). It would entail a large, off-stream storage impoundment constructed about 4 miles upstream of Pond 3.

- Media-Specific Action 6B. This option would entail construction of a much smaller, off-stream settling basin at the same location as Media-Specific Action 6A. This new pond would primarily provide settling of suspended solids and would have a much lower capacity for storing flood flows for slow release to the pond treatment system. Preliminary analysis of settling characteristics indicate that a pond approximately one-fourth the size of Media-Specific Action 6A would provide nearly the same settling efficiency as the larger pond.

Each of these options is described in the following subsections.

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MEDIA-SPECIFIC ACTION 6A: CONSTRUCT AN UPSTREAM FLOOD IMPOUNDMENT

The goal of Media-Specific Action 6A is to prevent large quantities of sediments and dissolved metals entrained in flood flows from passing through the operable unit and flowing into the Clark Fork River. This would be accomplished through the construction of a new, unlined pond designed to promote sedimentation of flood-entrained materials and store floodwaters for possible slow release to Pond 3 for treatment, if chemical analysis indicates that treatment is warranted. Assuming continual discharge of 600 cfs, the

100-year flood volume of 13,000 acre-feet could be captured and treated in the pond system.

This flood impoundment pond would act as a conventional sedimentation basin: as the influent velocity slowed in the pond, solids being transported by the flow would settle out. In addition, discharge from the pond under normal conditions would be restricted to less than 600 cfs, the maximum amount treatable in Pond 3. Because the pond would also lower flow rates downstream from its location, the potential would be substantially reduced for future erosion of the estimated 200,000 cubic yards of tailings that exist along Silver Bow Creek between the new pond site and Pond 3.

The 100-year flood was selected as the design event for the feasibility study because it is a flood frequency commonly used in designing structures to minimize the impacts of floods. No applicable or relevant and appropriate requirement specifies an appropriate level of protection to be provided by such a pond. The preliminary design is based on a 100-year Silver Bow Creek flood having a peak discharge of 4,000 cfs and a total runoff volume of 13,000 acre-feet over a 5-day period.[26]

A preliminary mass balance of inflow versus outflow to the pond indicated that the storage capacity could be less than 13,000 acre-feet. The reason is that the pond would only capture flows in excess of 600 cfs. During the 5 days of a normal 100-year event, 600 cfs would be continuously released from the impoundment and flow down Silver Bow Creek to the pond system. The preliminary mass balance indicated

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[26] CH2M HILL, 1988.

that a pond capable of storing 8,000 acre-feet could store the flows in excess of 600 cfs in Silver Bow Creek during a normal 100-year flood.

Throughout the 100-year event, flows in excess of 600 cfs would be diverted into the pond for collection, primary sedimentation, and metering into the downstream pond system for later treatment. By operating the upstream pond in this manner, the parts of it exposed to continual normal use would be reduced, thereby minimizing operation and maintenance costs for cleaning trashracks and replacing corroded facilities. This mode of operation also keeps the storage pond dewatered most of the time so that the required flood storage volume would be available to collect storm flows.

Flows in excess of the 100-year event would wash out a fuse plug, continue down Silver Bow Creek into the Mill-Willow Bypass, and on to the Clark Fork River.

The basic elements and structures required for the upstream flood impoundment include:

- Silver Bow Creek diversion dam (20-foot-high dike) and fuse plug spillway
- Silver Bow Creek control structure (radial gate structure)
- Storage pond inlet control structure (orifice control structure)
- Storage pond inlet channel

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- Storage pond (50-foot-high dike)
- Low-flow bypass channel through the storage pond
- Low-level outlet tunnel system
- Baffled apron spillway
- Spillway discharge channel

The hydraulic effects of each of the required structures are discussed in the following paragraphs. A site plan of the facilities is shown in Figure 7-10. Typical structures are shown in Figures 7-11 through 7-15.

A diversion dam on Silver Bow Creek would be required to divert the flow into the storage ponds. Diking upstream of the dam would also be needed to confine the flow within the existing flood boundary. The maximum dam and dike height would be about 20 feet. A fuse plug built into the dam would wash out at flows greater than 4,000 cfs. Figure 7-11 shows a typical dam section.

An approximately 30-foot-wide radial gate control structure would be provided on Silver Bow Creek. This structure would allow flows within the treatable flow rate (less than 600 cfs) to continue down Silver Bow Creek with a relatively normal flow pattern and would limit ponding behind the diversion dam. The radial gates would be closed automatically or manually when the flow exceeds the treatable rate. An actuation or warning system signaling the exceedance of the treatable flow rate could be activated by a water-surface sensing device. In the event the automatic system did not operate,

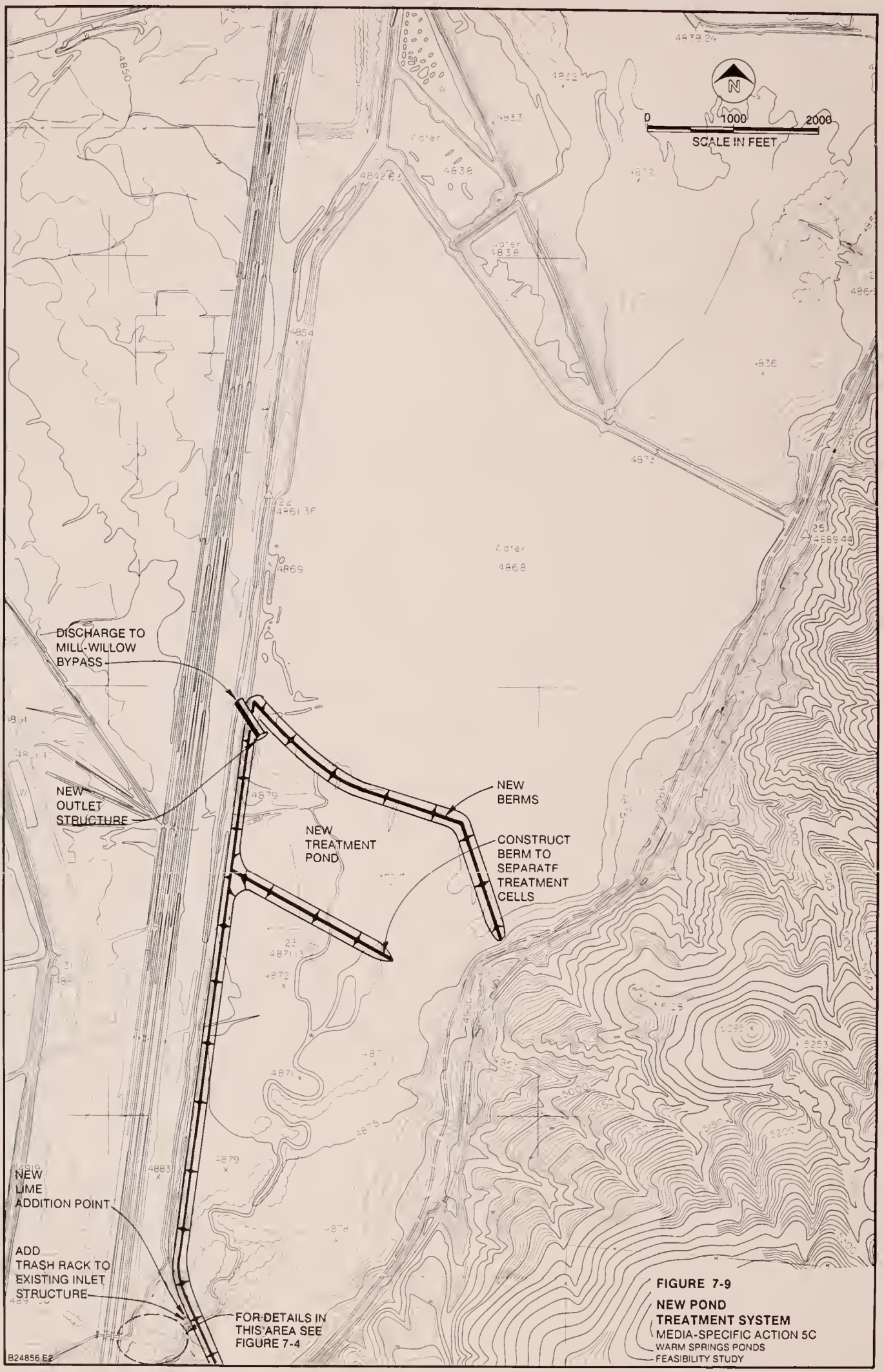


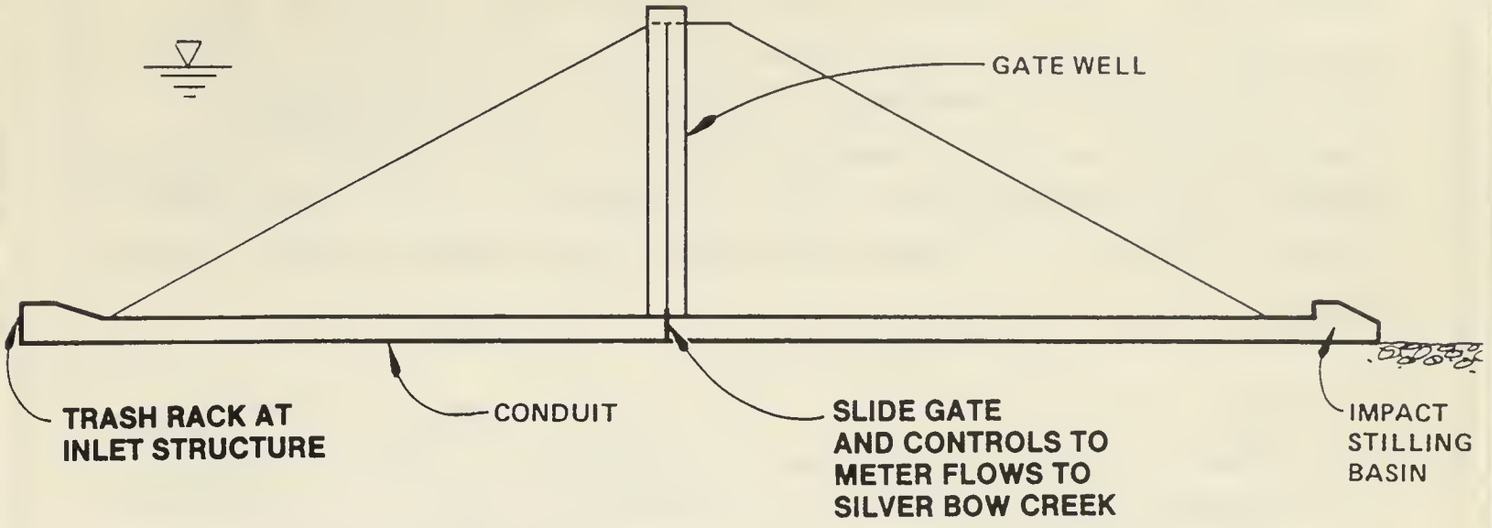
FIGURE 7-9

NEW POND TREATMENT SYSTEM

MEDIA-SPECIFIC ACTION 5C

WARM SPRINGS PONDS

FEASIBILITY STUDY



LOW LEVEL OUTLET TUNNEL SYSTEM

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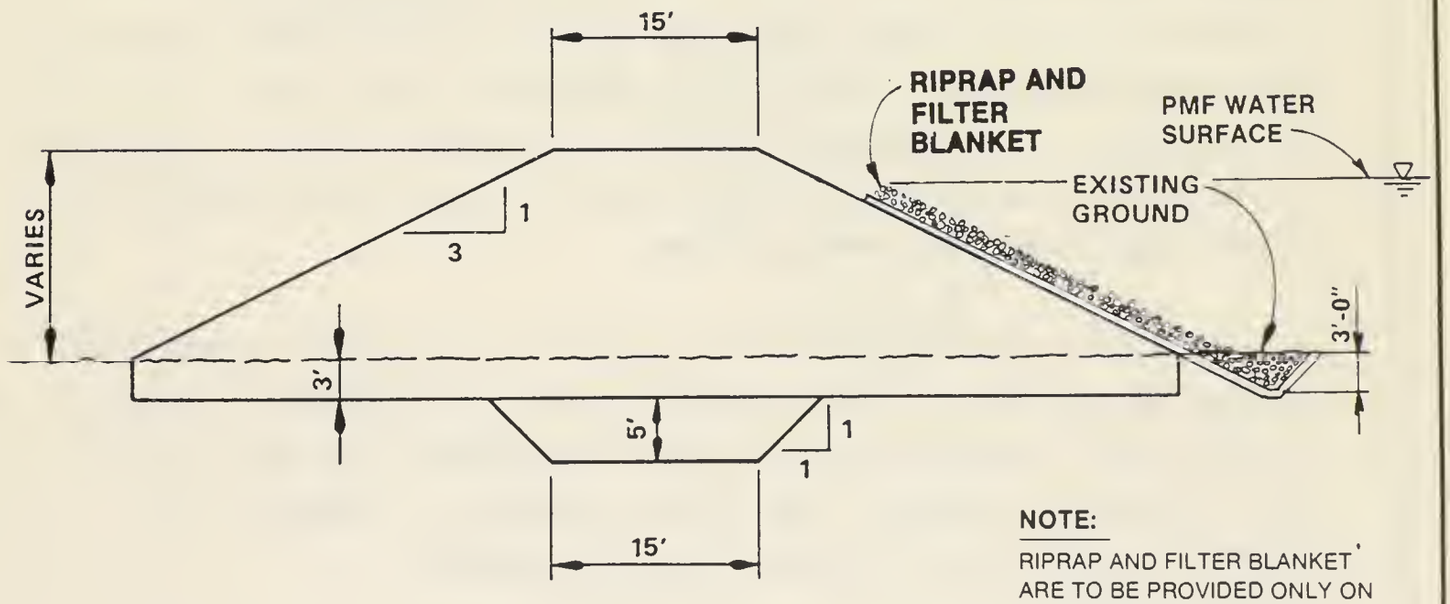

TYPICAL DAM OR DIKE SECTION

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NOTE:

RIPRAP AND FILTER BLANKET ARE TO BE PROVIDED ONLY ON THE OUTSIDE OF THE EAST STORAGE POND DIKE.

FIGURE 7-11

EXAMPLES OF A TYPICAL OUTLET SYSTEM AND DIKE SECTION FOR CONTAINMENT POND DESIGN

MEDIA-SPECIFIC ACTIONS 6A AND 6B

WARM SPRINGS PONDS FEASIBILITY STUDY

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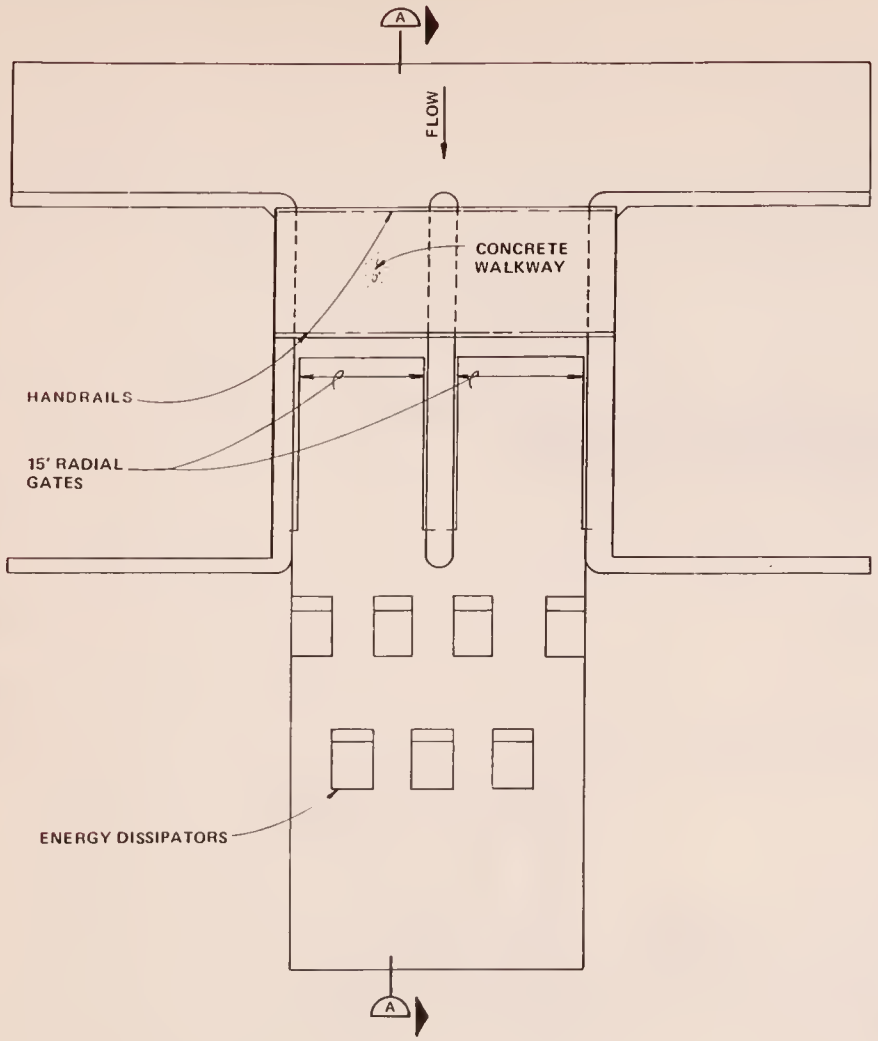
stop logs could be inserted to control flows. It should be noted that if the radial gate system failed and stop logs were not inserted, there would not be any hydraulic risk to the off-channel impoundment facilities. The only consequence would be that flows greater than 600 cfs would bypass Pond 3 and flow untreated down the bypass to the Clark Fork River. Figure 7-12 shows the Silver Bow Creek control structure.

An inlet structure would be necessary to control flows into the flood control pond. The orifice inlet structure shown conceptually in Figure 7-13 has a raised invert to keep low flows from entering the ponds. When the radial gate control structure is closed, the water surface would rise, allowing water to enter the pond through the orifice. The orifice would allow a maximum volumetric flow rate of 4,000 cfs, the peak flow rate of a 100-year flood, to enter the pond under normal operating conditions. For flows greater than 4,000 cfs, water would begin to spill over the fuse plug in the diversion dam. The orifice structure could be susceptible to plugging by debris and would require cleaning to maintain its capacity and prevent a fuse plug washout at flows less than the design flow.

A pond inlet channel would be needed to transport flow from Silver Bow Creek to the storage pond. It would be riprap-lined, have a bottom width of approximately 100 feet, and have levees to control the flood boundary. Figure 7-14 shows a section of a typical inlet channel.

The off-channel pond would have a storage capacity of approximately 8,000 acre-feet. The maximum dike height would be about 50 feet. Pond dikes were conceptually designed assuming material onsite is suitable for construction. No



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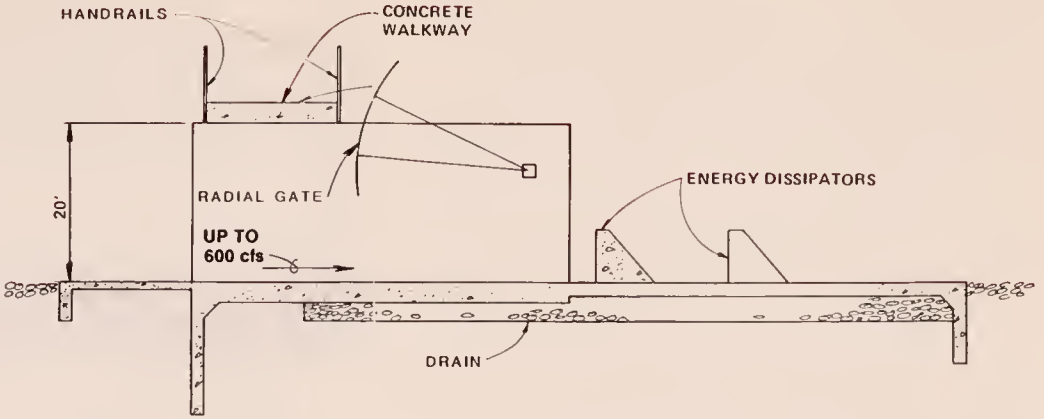

SECTION A

SILVER BOW CREEK RADIAL GATE CONTROL STRUCTURE
NTS

FIGURE 7-12

CONCEPTUAL DESIGN OF A
SILVER BOW CREEK
RADIAL GATE CONTROL STRUCTURE
MEDIA-SPECIFIC ACTIONS 6A AND 6B
WARM SPRINGS PONDS
FEASIBILITY STUDY

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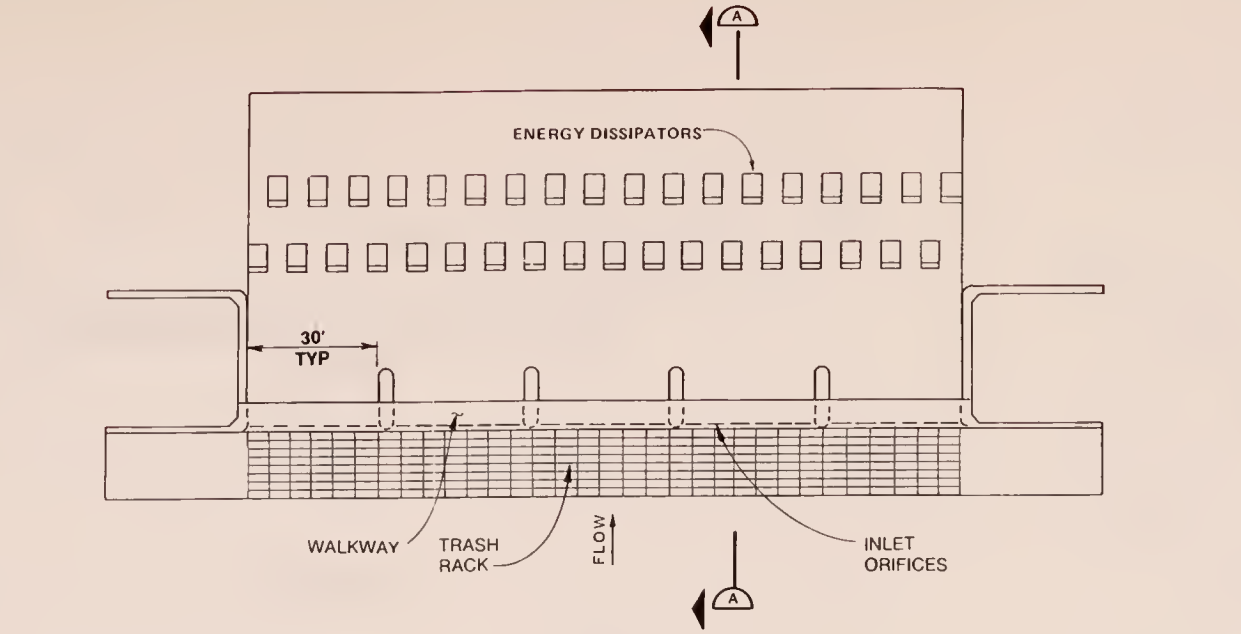

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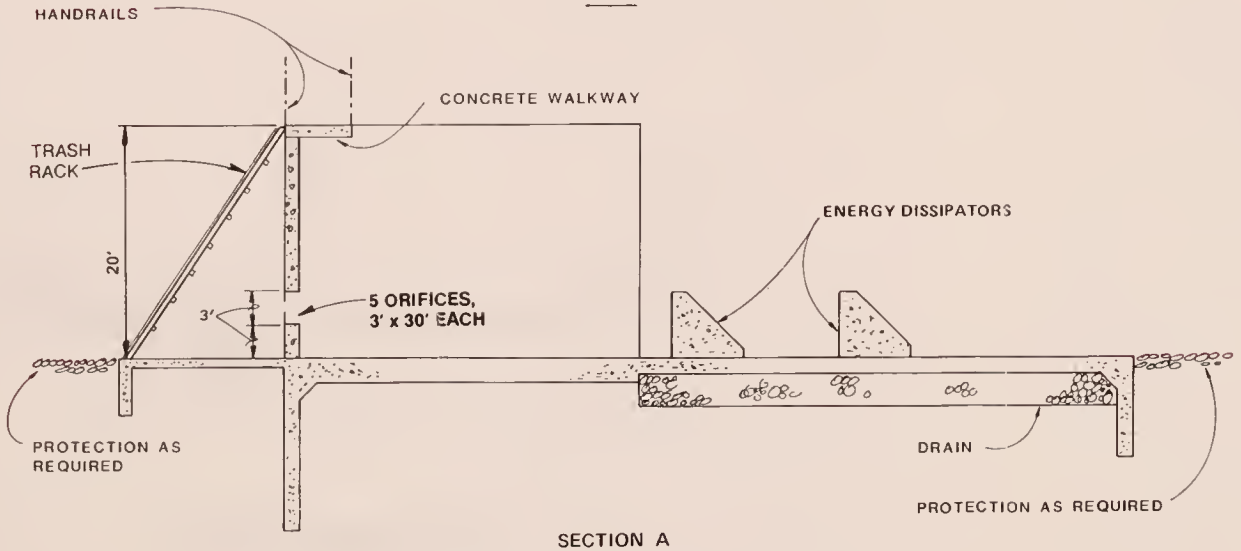

SECTION A

ORIFICE POND INLET CONTROL STRUCTURE
NTS

FIGURE 7-13

CONCEPTUAL DESIGN OF AN ORIFICE INLET STRUCTURE FOR THE SILVER BOW CREEK CONTAINMENT POND

MEDIA-SPECIFIC ACTIONS 6A AND 6B

WARM SPRINGS PONDS
FEASIBILITY STUDY

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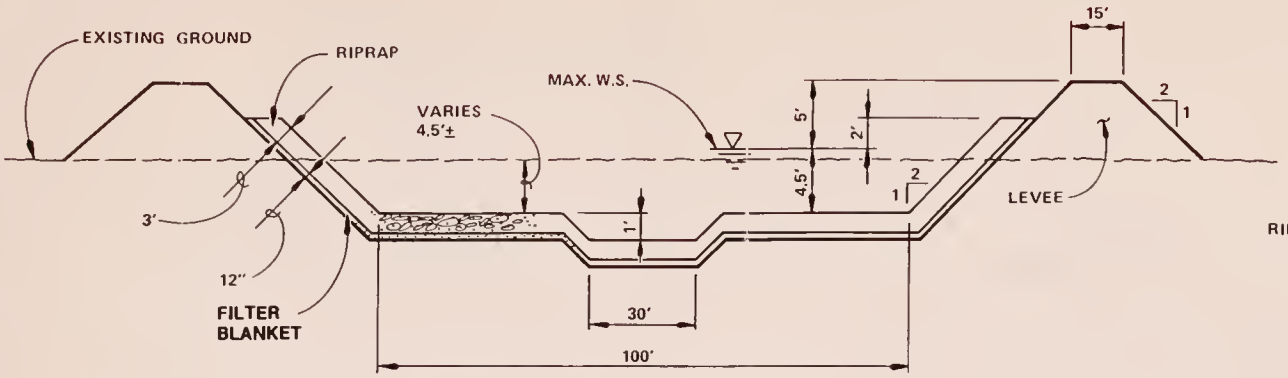

INLET CHANNEL
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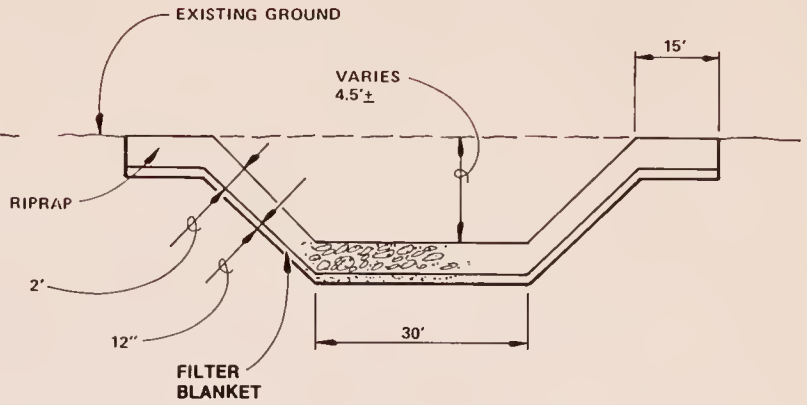

LOW FLOW BYPASS CHANNEL
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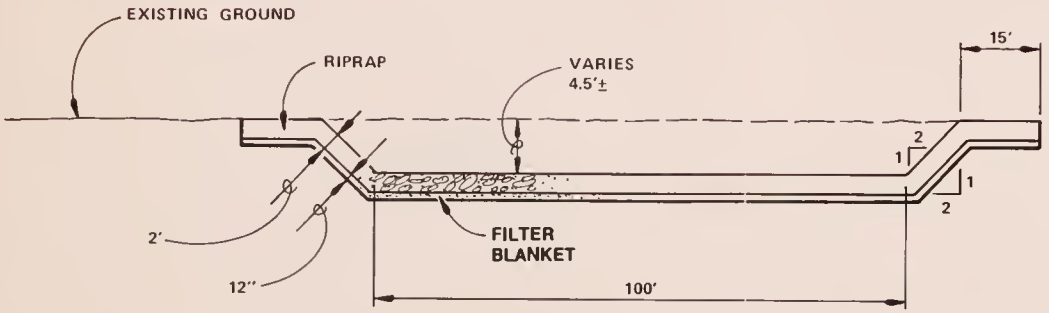

SPILLWAY DISCHARGE CHANNEL
NTS

FIGURE 7-14

EXAMPLES OF TYPICAL CHANNEL STRUCTURES FOR CONTAINMENT POND DESIGN

MEDIA-SPECIFIC ACTIONS 6A AND 6B
WARM SPRINGS PONDS
FEASIBILITY STUDY

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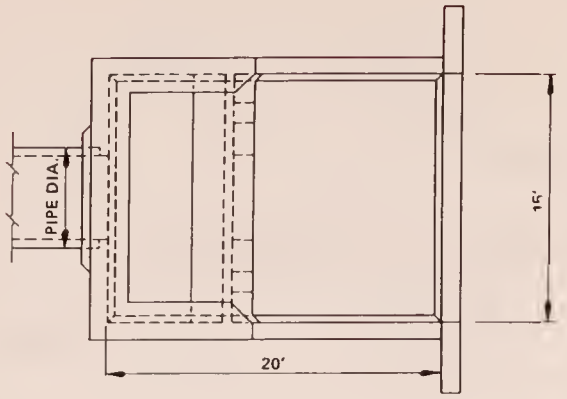

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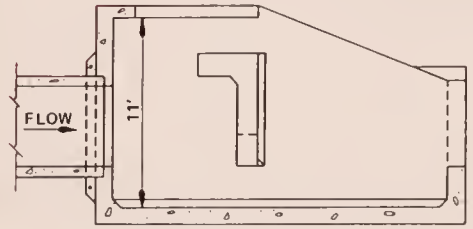
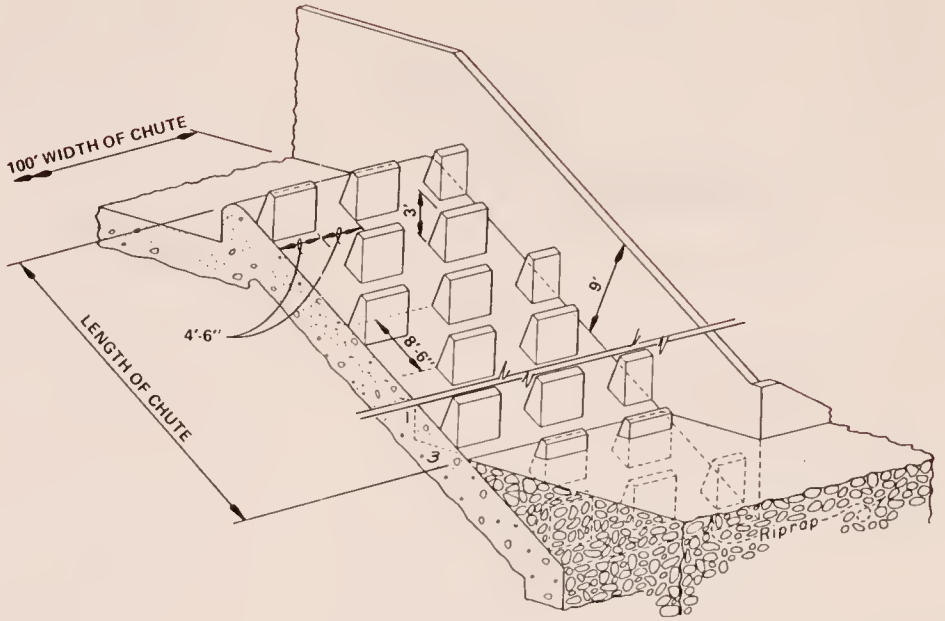


SECTION

LOW LEVEL OUTLET
IMPACT STILLING BASIN
NTS



BAFFLED APRON SPILLWAY
NTS

FIGURE 7-15

EXAMPLES OF TYPICAL STILLING BASIN AND SPILLWAY FOR CONTAINMENT POND DESIGN
MEDIA-SPECIFIC ACTIONS 6A AND 6B
WARM SPRINGS PONDS
FEASIBILITY STUDY

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subsurface information is currently available at the site; subsurface investigations would be required during the design phase. For quantity and cost estimating purposes, the dike section, shown in Figure 7-11, assumes 3:1 (horizontal: vertical) upstream and downstream slopes, a 3-foot stripping depth, and a 5-foot-deep core trench.

To minimize scour in the pond bottom, initial flows would be routed through the storage pond using a low-flow bypass channel. A typical low-flow bypass channel is shown in Figure 7-14.

A low-level pond outlet tunnel system would be used to pass flows from the pond back to Silver Bow Creek. For estimating purposes the system was assumed to consist of a trash-rack inlet structure, conduit through the dike, gate well and controls going through the dike, and an energy dissipator at the downstream end of the tunnel. A typical system is shown in Figure 7-11. Other systems for controlling the low-level outlet flows would be investigated during the design phase. These facilities would need to provide the capacity to drain the ponds in a reasonable amount of time. A nominal 4.5-foot diameter conduit would have a capacity of about 500 cfs, and an impact stilling basin could be used to provide energy dissipation. An impact stilling basin is shown in Figure 7-15.

Once the flows in Silver Bow Creek receded to near normal levels, the radial gate structure could be opened and the flow allowed to travel directly down the creek channel. The creek flow would be joined by the 500 cfs outlet flow from the pond, and the combined flow would be routed through the pond treatment system for treatment.

A spillway would pass flows through the pond when it is full. A conceptual spillway design used for cost estimating purposes is shown in Figure 7-15.

A spillway discharge channel with a bottom width of approximately 100 feet would be provided to transport high turbulence flow away from the dikes to limit scour. A discharge channel design is shown in Figure 7-14.

The structures for this option are dependent upon the stage and discharge of a probable maximum flood through the reach. Either a PMF would have to be diverted away from the pond, or a spillway with the capacity to pass some portion of a PMF would have to be added. For this feasibility study, it was assumed that the pond would be an off-channel structure and that a PMF would be routed around the storage facility. The diversion structure would be designed to wash out in large floods. Thus, the pond would not receive flows above a maximum volumetric flow rate of 4,000 cfs, and would not require a PMF spillway. This substantially reduces costs over an on-channel pond.

MEDIA-SPECIFIC ACTION 6B: CONSTRUCT AN UPSTREAM SETTLING BASIN

The construction of an upstream settling basin would be similar to Media-Specific Action 6A, except that the storage capacity would be much lower. The goal of the upstream settling basin would only be to settle out a major fraction of the flood-borne, metals-contaminated sediments, rather than to also store the flows for later controlled release for treatment in the pond system. The settling basin would be situated at the same location as the flood impoundment and its flow control structures would be similar. The primary

difference is that the settling basin would have approximately one-fourth the storage capacity of the flood impoundment. At one-fourth of the size, a reasonable comparison can be made of the costs versus treatment potential between the flood impoundment and the settling basin. The settling basin would have a storage capacity of about 2,000 acre-feet and have the capability of storing the anticipated volume of a 1,000-cfs peak flood in Silver Bow Creek lasting roughly 24 hours. The primary features of the settling basin are shown in Figure 7-16.

The diversion dam, inlet structure, low-flow channelization, and outlet structures would be virtually identical to those for the flood impoundment. This means that flows up to the 100-year flood peak volumetric flow rate (4,000 cfs) would be diverted into and through the settling basin. As with the flood impoundment, flows in excess of 4,000 cfs would wash out the fuse plug at the diversion dam and continue down Silver Bow Creek.

For floods whose volumes were less than 2,000 acre-feet, the metals removal process would be similar to that described in Media-Specific Action 6A. The flood flows would be stored and released at a maximum rate of up to 500 cfs for later treatment at the downstream ponds. For floods with volumes greater than 2,000 acre-feet, however, the lower storage capacity of the settling basin would result in a different treatment process.

After the storage capacity of the settling basin was reached, it would begin to function only as a sedimentation basin. After the pond is filled, Silver Bow Creek flows (up to about 4,000 cfs) would continue to be diverted into the basin. The primary discharge would be over the spillway,

providing detention time so that a portion of the suspended sediments could settle out. The flow over the spillway would carry substantially less tailings than it had on entering the basin. However, the flow rate over the spillway would exceed the capacity limit of the pond treatment system (600 cfs) and that portion above 600 cfs would be routed around the ponds, through the bypass, and into the Clark Fork River without treatment for dissolved metals.

Preliminary analysis of the removal potential through simple sedimentation indicates that this process could remove a significant portion of the suspended solids. The theoretical detention time in the settling basin at 4,000 cfs would be approximately 6 hours. Because a sedimentation basin does not perform perfectly (due to currents, short-circuiting, etc.), the theoretical detention time must be reduced for analysis purposes. A typical reduction factor for a basin of this type is 40 percent. In other words, the detention time for analysis should be reduced to 60 percent of the theoretical detention time, or 3.5 hours.

The use of Stokes Law provides a means of calculating the removal of contaminant-bearing particulates in the settling basin. In a 2,000-acre-foot settling basin, the smallest particle captured during a 100-year flood (4,000 cfs) would be about 20 microns in diameter. Based on available particle size data, this translates to approximately 80 percent (weight basis) removal of particulates from the flood flow. Although particle capture efficiency in the settling basin would be less efficient than for the larger flood impoundment, it may be reasonable to assume that the difference in basin size (2,000 versus 8,000 acre-feet) does not greatly reduce particulate removal efficiency. As noted previously,

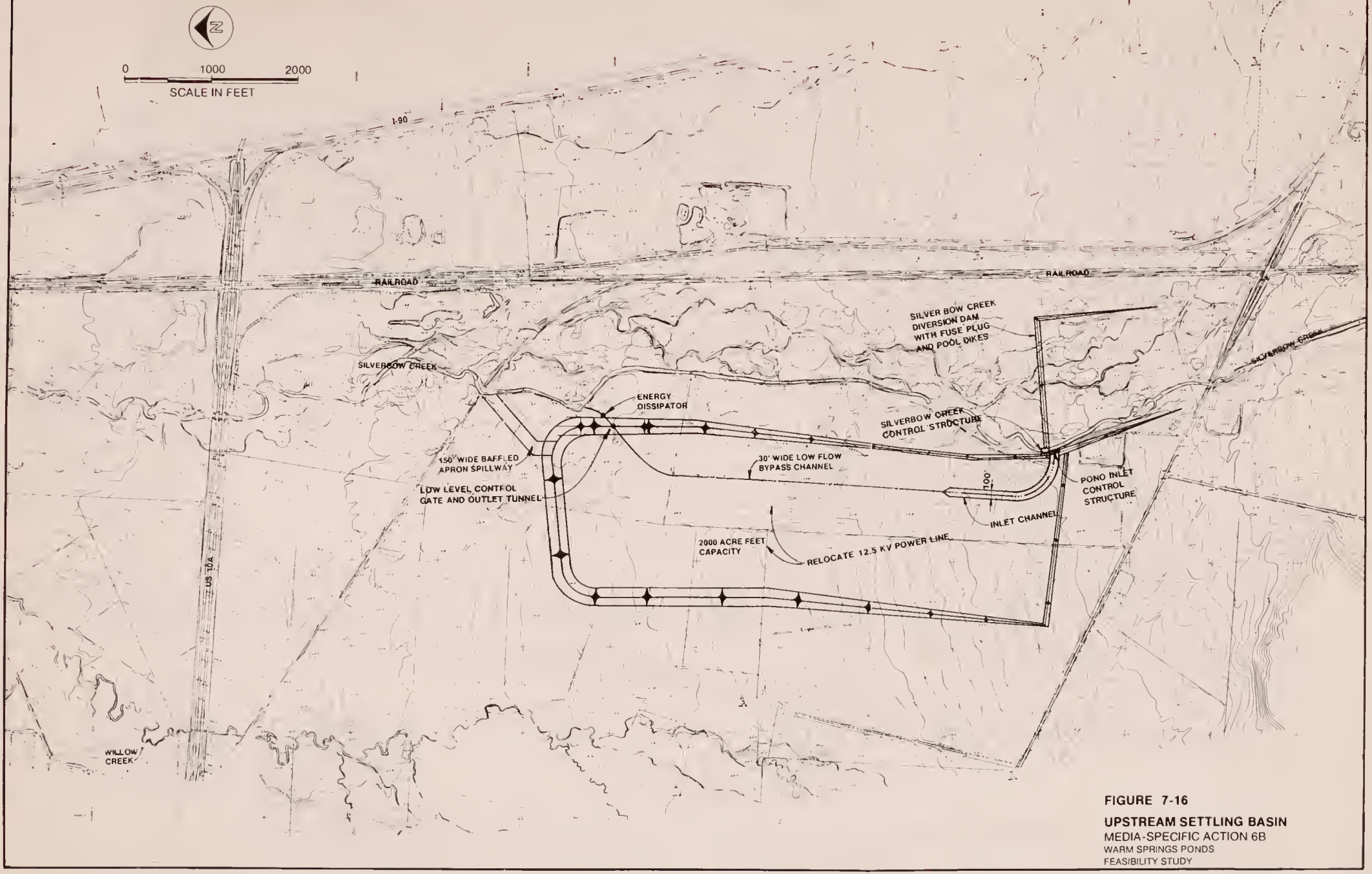

FIGURE 7-16

UPSTREAM SETTLING BASIN
MEDIA-SPECIFIC ACTION 6B
WARM SPRINGS PONDS
FEASIBILITY STUDY

a 2,000 acre-foot settling basin was chosen to provide a cost comparison of settling versus capturing and treating the flood flows. The precise size of the settling basin would be optimized during the design phase.

MEDIA-SPECIFIC ACTIONS 7, 8, 9, AND 10: ISOLATING TAILINGS AND CONTAMINATED SOILS

To limit environmental exposure and exposure due to direct human contact and airborne dust inhalation, it is necessary to isolate the tailings and contaminated soils within the operable unit.

LOCATIONS OF TAILINGS AND CONTAMINATED SOILS

There are more than 600 acres containing exposed or partially vegetated tailings and metal salt-contaminated soils within the boundary of the site.[27] The locations of the tailings deposits have been identified and mapped in the remedial investigation. Figure ES-1 shows the locations of the exposed tailings.

The locations and extent of the tailings and contaminated soils have been identified as follows:

Areas below Pond 1	76 acres
Exposed areas in Pond 1	59 acres
Exposed areas in Pond 2	155 acres
Along the Mill-Willow Bypass	54 acres
Areas above Pond 3	290 acres

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27 CH2M HILL, 1989.

These areas are described below. In addition, there are areas of vegetated sediments in Ponds 1 and 2 that may also require remediation. Table 2-2 provides a more detailed listing of the areas and volumes.

Areas Below Pond 1

The tailings below Pond 1 primarily lie along the historic channel of Silver Bow Creek and were likely deposited before the ponds were constructed. The quantity of tailings in this area has been estimated to be approximately 475,000 cubic yards. Therefore, over the approximately 76 acres of area below Pond 1, the average depth of tailings is approximately 3-1/2 feet.

Exposed Areas in Pond 1

Pond 1 is no longer used as part of the treatment system for Silver Bow Creek. It is filled with tailings and sediments and receives no direct influent from Silver Bow, Mill, or Willow Creeks.

The pond consists of three separate areas that roughly divide the former treatment pond into thirds. The eastern third of the pond supports an established wetland with large quantities of vegetation on the southern portion of the area and a large open water area on the northern part. Diverse flora and fauna populations exist in this area. The middle third of the pond consists primarily of tailings deposits and sediments with little vegetation or wildlife interaction.

The western third of the pond is primarily a dry, vegetated area with field grass and general vegetation covering the majority of the area. A few areas of exposed tailings are

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also found in the western third. The total volume of exposed tailings in Pond 1 has been estimated to be nearly 734,000 cubic yards. The vegetated or submerged sediments account for an additional 2,100,000 cubic yards.

Exposed Areas in Pond 2

Pond 2 contains a number of dry areas that have tailings deposits. These areas are shown in Figures ES-1 and 2-2. The tailings are primarily located in the southeast portion of the pond near the historic channel of Silver Bow Creek. The quantity of unsubmerged tailings in Pond 2 has been estimated to be 1,300,000 cubic yards (see Table 2-2).

Along the Mill-Willow Bypass

The tailings and contaminated soils along the Mill-Willow Bypass are discussed in detail in Media-Specific Action 4. Approximately 76,000 cubic yards of tailings deposits and 130,000 cubic yards of vegetated tailings and contaminated soils exist in the bypass.

Areas Above Pond 3

The southern (dry) portion of Pond 3 is relatively flat and well graded. There is a gentle slope from the south to the north. The area has historically held the natural channel of Silver Bow Creek, and the tailings in this area were deposited by the creek during the past 100 years of flow through the area. The quantity of tailings and contaminated soils in this area has been estimated at 1.22 million cubic yards (see Table 2-2). Approximately 7 to 8 percent of the tailings are unvegetated in this area.

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MEDIA-SPECIFIC ACTIONS

Four discrete options have been identified for isolating the tailings deposits and contaminated soils.

Each of these discrete options is discussed in detail in the following sections. In Chapter 8, these discrete options are combined in different ways to provide several alternatives for remediating the tailings deposits and contaminated soils.

MEDIA-SPECIFIC ACTION 7: CAP AND REVEGETATE TAILINGS DEPOSITS AND CONTAMINATED SOILS

This Media-Specific Action would cap and revegetate the contaminated areas. Capping and revegetating would potentially be appropriate for all areas except the tailings and contaminated soils along the Mill-Willow Bypass. The potential for erosion along the bypass means that the only viable action for these tailings and soils is to remove and dispose of them.

Capping would involve covering the contaminated areas with a 6-inch layer of tilled-in agricultural lime to reduce metals migration and then covering the whole area with 18 inches of imported soil. Fertilizer, soil amendment, and seed would be spread, as necessary, to establish a stable vegetative cover.

Native species would be used to establish the vegetative cover in order to minimize long-term maintenance costs. Careful scheduling of the planting would be required to ensure a good start for the plants. It is anticipated that

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some watering would be required during the establishment period, especially during dry spells.

Some periodic maintenance of the cover, or replanting as necessary, would also likely be required. The vegetated areas could be used as terrestrial wildlife habitat or to grow fodder for the wildlife at the site.

There are a number of considerations that should be noted with respect to capping and revegetating in the vicinity of Pond 1. The groundwater drains outlined in Media-Specific Action 11 and Media-Specific Action 12 would have to be constructed prior to the implementation of the capping option. This is necessary in order to dewater the soils sufficiently to allow a cap. Also, the area below Pond 1 could not be capped if wetlands treatment, Media-Specific Action 11, is selected for implementation, since that area would house the wetland. Finally, if Pond 1 is used for disposal of contaminated tailings and sediment as part of Media-Specific Action 10, certain RCRA regulations would be relevant and appropriate to the closure of the pond.

MEDIA-SPECIFIC ACTION 8: FLOOD TAILINGS DEPOSITS AND CONTAMINATED SOILS

This media-specific action proposes isolating the tailings deposits and contaminated soils by flooding them and keeping them covered with water. Flooding would be an appropriate option only for the tailings and contaminated soils below Pond 1, within Pond 2, and within Pond 3.

Flooding would not be an appropriate option for the tailings deposits and contaminated soils along the Mill-Willow Bypass.

As noted previously, removal and disposal is the only viable option for these tailings and soils.

Flooding also would not be an appropriate option for Pond 1. Recent measurements and calculations indicate that Pond 1, even though nearly empty of water and partially dewatered, is a significant source of contaminated recharge to the shallow aquifer below the pond. In order to eliminate this contaminant migration pathway, dry closure is the only viable option for Pond 1.

Flooding currently dry tailings and soils in other areas could also increase groundwater contamination. This point is discussed further in Chapter 8.

Below Pond 1

The flooding of tailings and contaminated soils below Pond 1 would be accomplished through the construction of the wetlands treatment system. The details of the wetlands are covered in Media-Specific Action 11.

Within Pond 2

The tailings and contaminated soils within Pond 2 could be flooded and a constant water level maintained in the pond. This option would require that Pond 2 be removed from service as a treatment pond (see Media-Specific Action 5A for details of decommissioning Pond 2).

A small berm would be designed to cross Pond 2, running east to west to facilitate the flooding of the higher, southern end of the pond. This gravel berm, which is shown in Figure 7-17, would be designed with 3:1 (horizontal to vertical) sideslopes. The berm would be designed high enough to

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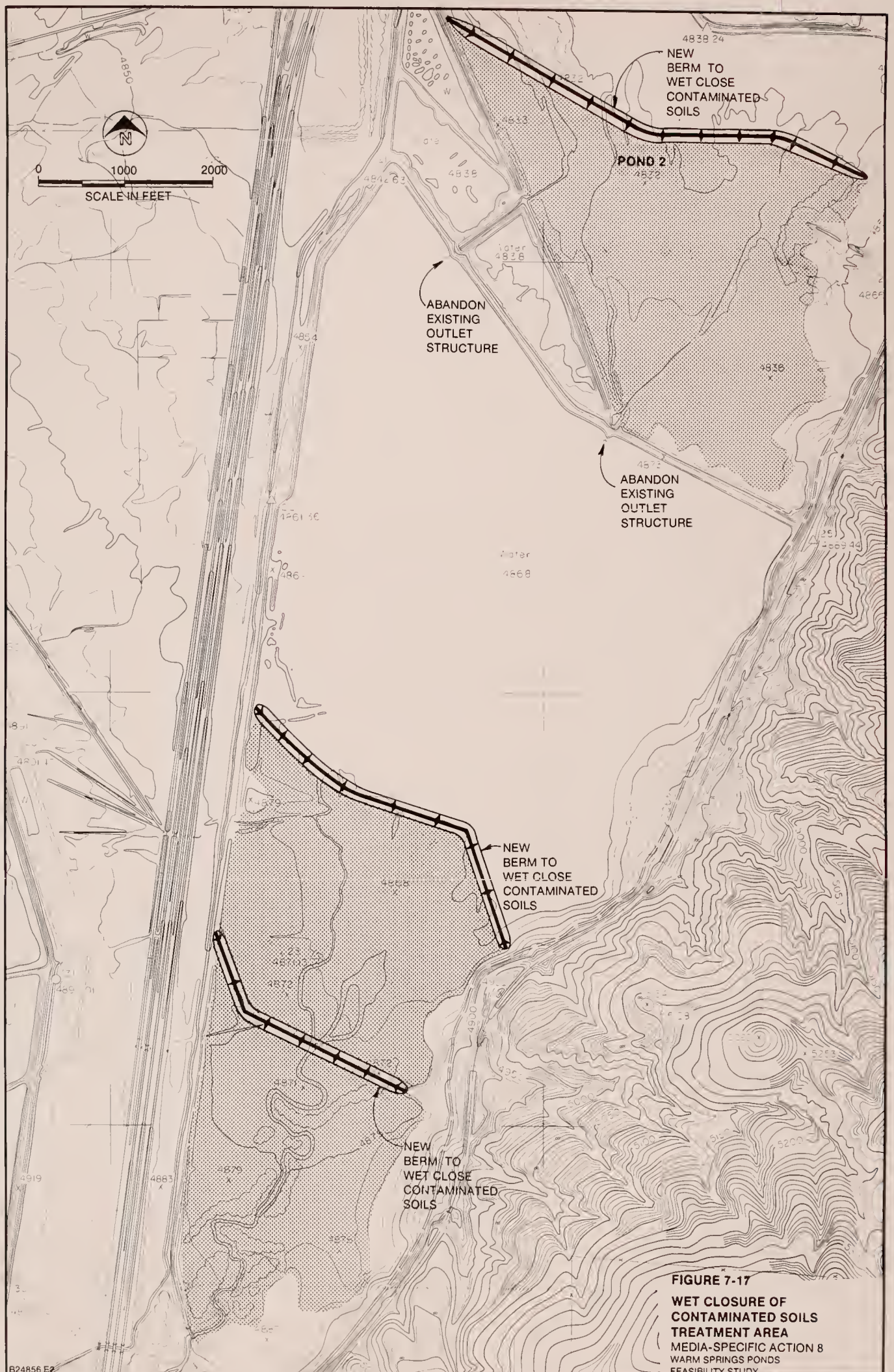

FIGURE 7-17

WET CLOSURE OF CONTAMINATED SOILS TREATMENT AREA

MEDIA-SPECIFIC ACTION 8

WARM SPRINGS PONDS FEASIBILITY STUDY

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maintain a minimum of 1 foot of water cover over the contaminated areas and maintain adequate freeboard for stability.

A small amount of flow would be discharged from Pond 3 to Pond 2 to keep both the newly bermed area and the established wetland areas covered with water. This is also important to prevent the buildup of salts in the flooded areas. Discharge from Pond 2 would flow directly into the Mill-Willow Bypass.

Within Pond 3

The southern portions of Pond 3 would be flooded using a system of small berms. Two berms would be used to completely flood the area. The berms would transect the area in an east-to-west direction. Preliminary berm locations are shown in Figure 7-17. They would be constructed using gravel and fill material obtained locally and would be built up using 3:1 sideslopes. The berms would be constructed high enough to provide at least a 1-foot water cover over the contaminated area and maintain adequate freeboard for berm stability.

Inflow to the flooded areas would be used to maintain a constant water surface and prevent salt buildup in the areas. The flooded areas would not be used for water treatment purposes. Influent would be fed directly from the Silver Bow Creek channel, as necessary. Discharge would be to Pond 3 for treatment.

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MEDIA-SPECIFIC ACTION 9: EXCAVATE FROM ALL APPLICABLE AREAS AND DISPOSAL IN AN OFFSITE RCRA FACILITY

This action assumes that the tailings and contaminated soils would be excavated from the applicable areas. This includes all areas of contaminated soils and tailings previously identified, except within Pond 1. As noted in Media-Specific Action 8, dry closure of Pond 1 is necessary to remove the source of groundwater contamination below Pond 1. This could be accomplished by removing all tailings and sediments in Pond 1. However, the volume of materials involved (2.9 million cubic yards) renders this option infeasible. Thus, the only option being considered for Pond 1 (other than solidification under Media-Specific Action 2) is to cap and revegetate the contaminated areas (Media-Specific Action 7).

Not all of the tailings and contaminated soils would have to be removed. The State of Montana and U.S. EPA have determined that only those materials that exceed the "action levels" for contaminants would need to be excavated and disposed of in an approved location. Action levels are contaminant concentrations which present an unacceptable health risk under human exposure conditions. The action levels for tailings deposits and contaminated soils have not yet been set. For the purposes of this feasibility study, action levels have been assumed at 250 mg/kg for arsenic and 750 mg/kg for lead. Data collected during the remedial investigation[28] indicate that approximately half of the exposed tailings deposits would have to be removed if these action levels were selected for the final cleanup.

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[28] CH2M HILL, 1989.

The excavated materials would be hauled offsite to a RCRA disposal facility. For cost estimating purposes, this feasibility study assumes that the nearest RCRA facility would be used. The closest RCRA disposal facility is Envirosafe Services, Inc., (ESI) near Boise, Idaho, which is approximately 480 road miles from the Warm Springs Ponds.

The requirement for disposal in a RCRA facility depends in part on whether the waste is defined as hazardous under RCRA (i.e., whether the tailings and contaminated soils fail the Extraction Procedure Toxicity Test, set forth in 40 CFR Part 261) and is otherwise within the jurisdictional requirements of RCRA. Based on previous analyses of tailings and contaminated soils, it is assumed that at least some of the excavated wastes would be classified as a RCRA hazardous waste. The Resource Conservation and Recovery Act requires that these hazardous wastes must be disposed of in a RCRA-permitted facility. Even if the wastes are not RCRA wastes, offsite disposal in a RCRA facility would ensure adequate protection to human health and the environment, as required by RCRA.

Also pursuant to RCRA, wastes containing free liquids cannot be landfilled. Because some sediments (especially those excavated from below Pond 1 and within Pond 2) will contain free water, they would therefore have to be dewatered.

The soil volumes for areas assumed to be excavated and the soils disposed offsite are equal to one-half of the exposed tailings in all areas except along the bypass where all of the material would be excavated. The calculated volumes are:

Area below Pond 1	38,700 cubic yards
Exposed areas in Pond 2	650,000 cubic yards
Along the Mill-Willow Bypass	206,000 cubic yards
Areas Above Pond 3	45,300 cubic yards

MEDIA-SPECIFIC ACTION 10: EXCAVATE FROM ALL APPLICABLE AREAS AND DISPOSAL ONSITE IN A RCRA-EQUIVALENT FACILITY

Contaminated materials which exceed the action level from below Pond 1, in Pond 2, from the Mill-Willow Bypass, and from unsubmerged areas within Pond 3 would be excavated as described in Media-Specific Action 9.[29] The excavated materials would be disposed of by placing them in Pond 1 prior to beginning the cap construction, or prior to solidification under Media-Specific Action 2. Although RCRA may not be fully applicable, certain RCRA requirements would be relevant and appropriate to this disposal method.

The cap construction would be similar to the capping specified for Media-Specific Action 7 except that an additional limited-permeability clay layer (24 inches) would be added between the lime and soil layers. This would limit percolation of surface water through the tailings to the groundwater. The requirements for closures of RCRA landfill units regarding dewatering, cap drainage, long-term structural integrity, and berm maintenance would be considered in designing the placement of the tailings and soil and in designing the cap. In order to maintain a viable vegetative cover, the cap would not include a synthetic membrane liner.

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[29] The discussion of which areas are applicable and the amount of soil to be excavated from each is included in Chapter 8.

MEDIA-SPECIFIC ACTION 11:
COLLECT GROUNDWATER AND TREAT IN A WETLAND BELOW POND 1

This Media-Specific Action addresses intercepting the contaminated groundwater flowing from Pond 1 toward the Clark Fork River and treating it in wetlands to be located below (north of) Pond 1.

GROUNDWATER COLLECTION

Contaminated groundwater would be collected by an open groundwater trench located north of the toe of the Pond 1 berm. The trench would be a minimum of 8 feet deep. The trench would be constructed similar to an agricultural drain with a trapezoidal cross section. The trench would slope toward a pump station located at the eastern end of the berm. Once the groundwater is collected at the pump station, it would be pumped up to the entrance to the wetlands for treatment. The total quantity of groundwater has been estimated at 1 cfs from this drain under steady-state conditions. The features of this groundwater trench and the wetlands are shown in Figure 7-18. The figure also contains a second groundwater trench located within Pond 1 only applicable to Media-Specific Action 12.

If required by space or aesthetic considerations, the groundwater trench could be constructed as an enclosed trench drain. This would require installation of a perforated (or open-joint) pipe at the bottom of the trench. The backfill material surrounding and above the pipe would have to be a free-draining gravel or cobble material. An enclosed trench drain would be considerably more difficult and expensive to construct than an open drain. This study assumes that the trench drain will not be enclosed.

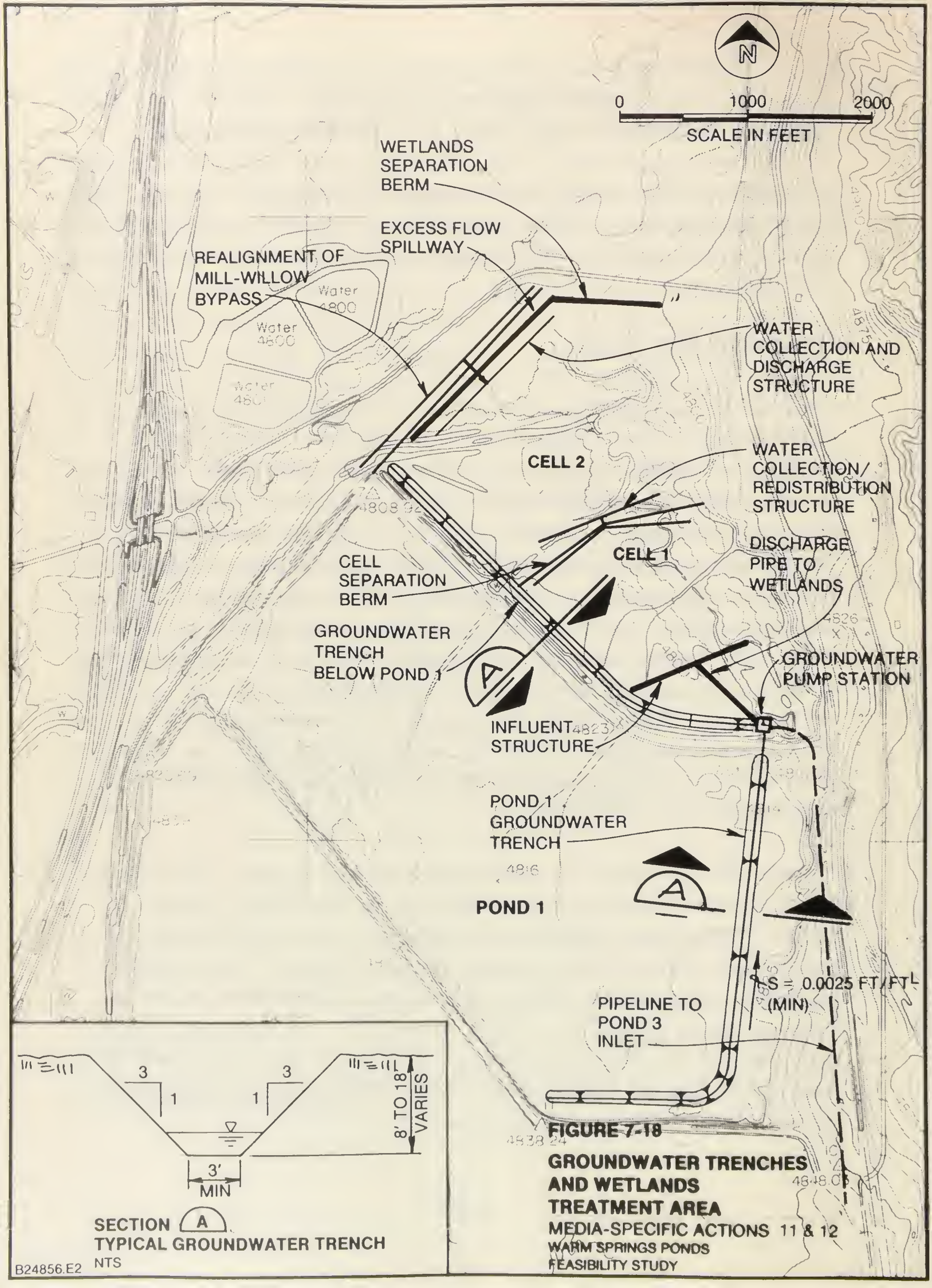

FIGURE 7-18

GROUNDWATER TRENCHES AND WETLANDS TREATMENT AREA

MEDIA-SPECIFIC ACTIONS 11 & 12

WARM SPRINGS PONDS FEASIBILITY STUDY

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WETLANDS TREATMENT

The area below Pond 1 would be converted into a wetlands treatment area. The area available for the wetlands treatment system covers approximately 100 acres. Based on a typical design loading rate of 1 gallon per minute per 500 square feet and an 80 percent usage of available land, the wetlands area would be able to receive up to 16 cfs of influent. The expected flow into the wetlands from the collected groundwater is approximately 1 cfs.

To convert the area into a wetlands treatment system, it would have to be regraded to create containment berms capable of holding a sufficient quantity and depth of water. In addition, the tailings and contaminated soils in the area (average 3-1/2 feet deep over the majority of the area) would be removed prior to construction of the wetlands.

Two separate treatment cells would be set up within the area to enhance the metals removal efficiencies of the overall system. The cells would operate in a series configuration with effluent water from the first cell discharged into the second cell.

The soil on the floor of the wetlands cells would be a mixture of native soil and an imported topsoil or mulch high in organic matter. The organic matter would be needed as a substrate for transplanted vegetation, because it encourages vegetation establishment and microbial colonization. The wetlands system would generally be vegetated with cattails, reeds, grasses and additional local species taken from existing wetlands in the area. Species would be selected based on metal tolerance, uptake patterns, and wildlife use (both for food and shelter). Species of cattails and reeds have been noted for their tolerance of high metal loadings, and both are prevalent in existing wetlands areas in Ponds 1 and 2.

The wetlands would be designed with an average water depth of approximately 5 to 7 feet, although a wide variation in depth would be built into the system. This depth would give the wetlands a detention time of approximately 15 days, common for similar systems. In the shallower portions of the wetlands (i.e., less than 2 feet), wetland-emergent vegetation would be expected to dominate and cover the area. Deeper areas (greater than 2 feet) would generally be open, encouraging algal growth.

The influent from the pump station would flow into a discharge structure along the southeastern corner of the wetland area where it would be distributed along the length of the treatment cell, 500 to 800 feet, using a simple nonpoint overflow weir.

After passing through the first cell, the water would be collected using a nonpoint overflow weir and passed to the second treatment cell where it would be redistributed. At the downstream side of the second treatment cell the water would again be collected in a nonpoint overflow weir structure and discharged to the Clark Fork River. Piping for the system would be selected to withstand corrosion, and all of the conveyance system would be designed for easy flushing to prevent sediment buildup.

Due to seasonal vegetative die-off, periodic removal of organic matter from the wetlands area would be necessary. This could be done as a coordinated effort to produce food for onsite fauna or strictly as a maintenance effort every few years to keep the wetlands clean and operating effectively. If the removed organic matter contains levels of metal contamination that make it a hazardous waste, disposal

of this waste in a permitted landfill would be an additional operation and maintenance cost. With periodic cleaning performed as outlined above, the wetlands area would be expected to remain viable for approximately 70 to 80 years.

MEDIA-SPECIFIC ACTION 12: GROUNDWATER COLLECTION IN AND BELOW POND 1 WITH TREATMENT IN POND 3

This media-specific action would be similar to Media-Specific Action 11 in that it would collect and treat groundwater flowing under the Pond 1 berm. It would differ from Media-Specific Action 11 in that it would incorporate an additional groundwater trench within Pond 1 and a pump station capable of pumping all of the groundwater back to Pond 3 for treatment. A wetland treatment system would not be constructed under this media-specific action.

GROUNDWATER COLLECTION

The groundwater trench at the downstream toe of the Pond 1 berm would be similar to the trench outlined in Media-Specific Action 11.

The trench located within Pond 1 would serve three purposes: dewater Pond 1 to facilitate dry closure of the pond (see Media-Specific Action 10); alleviate groundwater quality degradation in the vicinity of ponded water in Pond 1; and cut off flow of uncontaminated groundwater from the eastern hills. The location of the trench within Pond 1 is shown on Figure 7-18.

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As noted in Media-Specific Action 10, Pond 1 could be used for onsite disposal of contaminated soils and tailings. It will be necessary to dewater the existing ponded areas and to decrease the free water within the saturated soils before this could be accomplished.

Groundwater quality samples collected from shallow monitoring wells located immediately adjacent to and downgradient of the ponded water in Pond 1 exhibit the highest metals concentrations measured in monitoring wells within the operable unit. Elevated metals concentrations measured in shallow monitoring wells near the ponded water in Pond 1 are likely attributable to the presence of standing water in Pond 1. Groundwater quality samples collected from shallow monitoring wells completed west of standing water in Pond 1 exhibit significantly lower metals concentrations.[30]

The topography of Pond 1 indicates standing water in Pond 1 originates as seepage water emanating through the base of the eastern portion of the Pond 2 berm, where the historic Silver Bow Creek channel intersects the shallow water table. The groundwater collection trench at the toe of the Pond 2 berm (see Figure 7-18) would be expected to capture this seepage water and eventually drain saturated material in Pond 1 to below the base of tailings contained in the pond.

Groundwater flowing from the eastern hills likely becomes contaminated through contact with the tailings in Pond 1. In addition, it also likely contributes to the saturated conditions within the pond. This uncontaminated groundwater

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30 CH2M HILL, 1989.

would be intercepted by the trench before it comes in contact with the tailings in Pond 1.

A single "dog-leg" interception trench located as shown in Figure 7-18 would accomplish all of the necessary dewatering. The portion of the trench located below the Pond 2 berm would intercept seepage from Pond 2. The north-south portion of the trench would serve to dewater the tailings and to intercept groundwater from the eastern hills.

As with Media-Specific Action 11, an open trench could be constructed similar to an agricultural drain. It would vary from 8 to 14 feet deep and would drain toward the groundwater pump station. A culvert would carry the groundwater beneath the Pond 1 berm and into the pump station.

GROUNDWATER TREATMENT

The pump station would be located to collect the flows from both of the groundwater drains. It would then pump the collected flows through a pipeline located along the eastern edge of the ponds to a discharge at the inlet to Pond 3. Treatment of the groundwater would then be accomplished in Pond 3.

The maximum pumping rate from both trenches is estimated to be about 2 cfs under steady-state conditions. The pump station would be designed to pump this flow with 100 percent redundancy. Thus, the pump station would require two 50-horsepower pumps. The pipeline is assumed to be 12 ductile iron pipe. The required length of the pipeline depends on the media-specific action chosen for upgrading or replacing

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the existing pond system, and varies from 4.25 miles (Media-Specific Action 5A) to 5.0 miles (Media-Specific Action 5-C).

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Chapter 8
ASSEMBLY AND ANALYSIS OF ALTERNATIVES

This chapter describes the final steps in the feasibility study process: the assembly and analysis of remedial action alternatives for the operable unit. The alternatives are constructed by combining one or more media-specific actions for each of the affected media into an overall remediation package. Seven alternatives are assembled from the 16 media-specific actions (including options) conceptualized in Chapter 6 and developed in Chapter 7. The alternatives are developed to present a range of possible combinations. The assembled alternatives are also analyzed, both individually and comparatively, against seven of the nine criteria developed by the USEPA[1]. This analysis, along with the two remaining criteria, community and support agency acceptance, will be used to provide a basis for evaluation by state and USEPA decisionmakers when they compare alternatives and select a remedy. Ultimately, remedy selection must be consistent with the requirements of CERCLA and the National Contingency Plan.

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DEVELOPMENT OF ALTERNATIVES

In Chapter 7, the 16 media-specific actions (including options) were developed in detail as discrete problem solving actions, each focusing on one (or at the most, two) of the

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[1] USEPA, 1988. Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA (Interim Final, October 1988), 6-3 to 6-13.

major ARARs violations or human health and environmental concerns. Each media-specific action was developed separately, with limited inquiry into how they would interact or fit together into comprehensive alternatives for the entire operable unit. In this chapter, the media-specific actions are combined to address all of the ARARs violations and human/environmental health concerns at the operable unit. These combinations form the various remedial action alternatives that will be considered for the entire operable unit.

There are four actions for the pond bottom sediments, six for surface water, four for tailings deposits and contaminated soils, and two for groundwater. If one action were selected for each of the media, there would be 192 possible combinations or alternatives. If more complex combinations were considered, the number of possible alternatives would be much larger. To keep the development and evaluation of the alternatives in this chapter manageable, seven alternatives have been selected to represent the range of possible combinations. The seven alternatives include six action alternatives and a no-action alternative. They are presented in Table 8-1. In the Record of Decision (ROD), the USEPA and the State may select an alternative presented here, or they may select an alternative combining different aspects of the presented alternatives based upon comments and concerns raised during the public comment period.

Table 8-2 lists the alternatives approximately in order of decreasing overall protectiveness, describing the components of each. Alternative 1 includes in situ solidification of all presently existing pond sludges and sediments to protect against flood and earthquake damage or loss. In situ solidification is an innovative treatment process that has

Table 8-1

MEDIA-SPECIFIC ACTIONS FOR EACH ASSEMBLED ALTERNATIVE

MEDIA-SPECIFIC ACTION		DESCRIPTION	ALTERNATIVE 1	ALTERNATIVE 2	ALTERNATIVE 3	ALTERNATIVE 4	ALTERNATIVE 5	ALTERNATIVE 6	ALTERNATIVE 7 (no action)
POND BOTTOM SEDIMENTS	1A	Stabilize pond berms to withstond a probable moximum flood.		●					
	1B	Stabilize pond berms to withstond flood flows less than the probable moximum flood.			●	●	●	●	
	2	Stabilize/solidify pond sediments.	●						
	3	Stabilize pond berms to withstond a maximum credible eorthquoke.		●	●	●	●	●	
SURFACE WATER	4	Remove and dispose of contominoted surfoce soils olong the Mill-Willow Byposs.	●	●	●	●	●	●	
	5A	Overoll upgrode of pond treotment system.		●	●	●			
	5B	Less comprehensive upgrade of pond treotment system.					●	●	
	5C	Construct o new treatment pond for continued water treotment.	●						
	6A	Construct on upstreom flood impoundment.	●	●					
	6B	Construct on upstreom settling bosin.			●	●	●		
TAILINGS DEPOSITS AND CONTAMINATED SOILS[1]	7	Cop and revegetote exposed tailings ond contominoted soils where feosible.				●	●		
	8	Flood exposed tailings ond contominated soils where feosible.						●	
	9	Excavote exposed toilings ond contominoted soils from oppropriate oreos; disposol ot on offsite, RCRA focility.		●					
	10	Excavote exposed toilings ond contominated soils from oppropriate oreos; disposol ot on onsite, RCRA-equivolent facility (Pond 1) either prior to solidificotion (Media-Specific Action 2) or prior to copping (Media-Specific Action 7).	●		●				
GROUNDWATER	11	Groundwater collection below Pond 1 with wetlond treotment.					●	●	
	12	Groundwoter collection in ond below Pond 1 with treotment in pond system.	●	●	●	●			

[1] Only the primory Media-Specific Action(s) for each alternative ore shown for Tailings Deposits and Contaminated Soils. Becouse of conditions inherent in the vorious areos, more than one action is typicolly required for remediotion of the tailings and soils.

J:\INDUST\BOI24856\TABLE8-2.DWG

Table 8-2
ASSEMBLED ALTERNATIVES FOR WARM SPRINGS PONDS OPERABLE UNIT FEASIBILITY STUDY

MEDIA:	Pond Bottom Sediments		Surface Water				Groundwater	Soil
Alt.	Sediments Floods	Sediments Earthquakes	Fishkills	Dissolved Metals	Erosion of Tailings	Transport of Upstream Tailings	Contaminated Groundwater	Exposed Tailings and Contaminated Soils
1	Cease current operation of the pond system and solidify sludges and sediments in all three ponds.	Cease current operation of the pond system and solidify sludges and sediments in all three ponds.	Remove exposed tailings and contaminated surface soils from bypass; dispose of in Pond 1, 2, or 3, and solidify.	Construct a new, more effective treatment pond.	Remove exposed tailings and contaminated surface soils from the bypass; dispose of in Pond 1, 2, or 3, and solidify.	Construct an upstream flood impoundment of 8,000 acre-feet.	Install trench drains in and below Pond 1. Pump to new treatment pond inlet for treatment.	Excavate all material above the action level;[a] disposal in Pond 2 or 3 prior to solidifying the ponds.
2	Protect ponds against a PMF.	Protect ponds against an MCE.	Remove exposed tailings and contaminated surface soils from the bypass; dispose of in an offsite TSDF.	Comprehensive upgrade of the Pond 3 treatment system.	Remove exposed tailings and contaminated surface soils from the bypass; dispose of in an offsite TSDF.	Construct an upstream flood impoundment of 8,000 acre-feet.	Install trench drains in and below Pond 1. Pump to Pond 3 inlet for treatment.	Excavate all exposed areas above the action level;[a] offsite disposal; cap and revegetate Pond 1 and flood Pond 2.
3	Protect ponds against fractions of a PMF.[b]	Protect ponds against an MCE.	Remove exposed tailings and contaminated surface soils from the bypass; dispose of in Pond 1 prior to capping.	Comprehensive upgrade of the Pond 3 treatment system.	Remove exposed tailings and contaminated surface soils from the bypass; dispose of in Pond 1 prior to capping.	Construct an upstream settling basin of 2,000 acre-feet.	Install trench drains in and below Pond 1. Pump to Pond 3 inlet for treatment.	Excavate all exposed areas above the action level;[a] disposal in Pond 1; cap and revegetate Pond 1. Flood Pond 2.
4	Protect ponds against fractions of a PMF.[b]	Protect ponds against an MCE.	Remove exposed tailings and contaminated surface soils from the bypass; dispose of in Pond 1 prior to capping.	Comprehensive upgrade of the Pond 3 treatment system.	Remove exposed tailings and contaminated surface soils from the bypass; dispose of in Pond 1 prior to capping.	Construct an upstream settling basin of 2,000 acre-feet.	Install trench drains in and below Pond 1. Pump to Pond 3 inlet for treatment.	Cap and revegetate all material above the action level. Excavate exposed tailings and contaminated soils in bypass; dispose in Pond 1 prior to capping. Flood Pond 2.
5	Protect ponds against fractions of a PMF.[b]	Protect ponds against an MCE.	Remove exposed tailings and contaminated surface soils from the bypass; dispose of in Pond 1 prior to capping.	Partial upgrade of the treatment system: replace fuse plug; improve trashrack and lime addition.	Remove exposed tailings and contaminated surface soils from the bypass; dispose of in Pond 1 prior to capping.	Construct an upstream settling basin of 2,000 acre-feet.	Install trench drains below Pond 1; treat in onsite wetlands.	Cap and revegetate all exposed areas above the action level. Excavate exposed tailings and contaminated soils in bypass; dispose in Pond 1 prior to capping. Flood Pond 2.

Table 8-2
(continued)

MEDIA:	Pond Bottom Sediments		Surface Water				Groundwater	Soil
Alt.	Sediments Floods	Sediments Earthquakes	Fishkills	Dissolved Metals	Eroaion of Tailings	Transport of Upatream Tailings	Contaminated Groundwater	Exposed Tailings and Contaminated Soils
6	Protect ponds against fractions of a PMF.[b]	Protect ponds against an MCE.	Remove exposed tailinga and contaminated aurface soils from the bypass; dispose of in Pond 1 prior to capping.	Partial upgrade of the treatment syatem: replace fuse plug; improve trashrack and lime addition.	Remove exposed tailinga and contaminated aurface soils from the bypasa; diapose of in Pond 1 prior to capping.	No action.	Install trench drains below Pond 1; treat in onsite wetlands.	Flood all applicable aress above the action level.[a] Excavate exposed tailings and contaminsted soils in bypass; dispose of in Pond 1 prior to capping.
7	No action.	No action.	No action.	No action.	No action.	No action.	No action.	No action.

[a]All areas containing contaminated soila and tailings for which the specified technology is appropriate or applicable. For example, excavation is appropriate above Pond 3, below Pond 1, and along the bypass; it ia not applicable for the tailings in Ponds 1 and 2. Preliminary action levels are 250 ppm for arsenic and 750 ppm for lead.
[b]Alternative would protect Pond 3 to a 0.5 PMF, Pond 2 to a 0.3 PMF, and Pond 1 to 0.2 PMF.
PMF = probable maximum flood
MCE = maximum credible earthquake

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not been extensively used for hazardous remediations. It has been included as an alternative that relies on treatment of wastes to reduce their mobility, in accordance with Superfund [CERCLA Subsection 121(b)(1)]. Because the three existing ponds would be solidified as part of Alternative 1, the alternative also includes the construction of a new treatment pond to continue the treatment of contaminated surface water currently provided by the existing ponds. An upstream flood impoundment is also part of this alternative.

Alternative 2 protects all three of the existing ponds against both a maximum credible earthquake (MCE) and a probable maximum flood (PMF) by stabilizing the berms of the ponds. It also includes an overall upgrading of the existing pond treatment system and the construction of an upstream flood impoundment.

Alternatives 3 through 6 all provide berm protection for each of the ponds against a full MCE and a fraction of a PMF (0.2, 0.3, and 0.5). They differ in the level of improvement to the pond treatment system and the use of a smaller upstream settling basin for flood and tailings control instead of an 8,000 acre-foot flood impoundment.

Each of the first six alternatives also includes one of the disposal or containment options for tailings deposits and contaminated soil, and one of the two groundwater remediation options developed in Chapter 7. All of the tailings and soils options apply a contaminant action level of 250 ppm for arsenic and 750 ppm for lead.

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Alternative 7 is the no-action alternative required under CERCLA and used as a baseline against which the other alternatives are evaluated.

The seven remedial action alternatives for the operable unit have been selected to include, to the extent possible and appropriate, at least one alternative in each of the following five regulatory categories: 1) treatment or disposal at an offsite facility (Alternative 2); 2) attainment of applicable or relevant and appropriate requirements (ARARs) (Alternatives 1 through 4); 3) exceedance of ARAR requirements (Alternatives 1 and 2); 4) reduction of the likelihood of present or future threat from hazardous substances, which provides significant protection to public health and welfare and the environment although not attaining all ARARs (Alternatives 5 and 6); and 5) a no-action alternative (Alternative 7).[2] The categorization of alternatives as complying with or exceeding the requirements of ARARs assumes a waiver will be granted for arsenic and mercury ambient water quality standards pursuant to regulations promulgated under the Montana Water Quality Act. Waivers for the arsenic and mercury standards are necessary because the promulgated standards cannot be met using current technology.

As discussed above, these seven alternatives are by no means the only alternatives that could have been assembled from the media-specific actions identified in Chapter 6 and developed in Chapter 7. The compiled alternatives present a varied range of remediation options in a workable number of alternatives for the decisionmakers to consider while

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2 40 CFR 300.68(e).

complying with the required statutory and regulatory requirements. By mixing and matching combinations of the media-specific actions, alternatives can be assembled to emphasize or de-emphasize any of the ARARs violations, human health or environmental concerns, or media as desired.

DETAILED ANALYSIS OF ALTERNATIVES

As the final step in the feasibility study process, the seven alternatives assembled above are analyzed to determine whether they satisfy specific statutory criteria, regulatory criteria, and additional criteria developed by the USEPA. The analysis is conducted by evaluating the seven alternatives, first individually and then comparatively, against seven evaluation criteria prescribed by the USEPA. Two additional criteria, support agency and community acceptance, are modifying considerations evaluated following the public comment period leading to the issuance of the Record of Decision. Table 8-3 provides a listing of the nine USEPA criteria and summarizes specific factors that further refine the criteria as they are to be used in the detailed analysis of the alternatives. The first seven criteria are described separately below. The first two criteria are threshold requirements expected of all alternatives. The remaining five criteria are the primary balancing factors used to differentiate among the alternatives.

Specifically, USEPA's evaluation criteria are:

1. Overall protection of human health and the environment. As a minimum standard or threshold criterion, Superfund

Table 8-3
CRITERIA FOR DETAILED ANALYSIS OF ALTERNATIVES

Protection of Human Health and the Environment	Compliance With ARARs	Long-Term Effectiveness	Reduction of Toxicity, Mobility, and Volume	Short-Term Effectiveness	Implementability	Cost	Support Agency Acceptance	Community Acceptance
How alternative provides human health and environmental protection	Compliance with contaminant-specific ARARs Compliance with action-specific ARARs Compliance with location-specific ARARs Compliance with other criteria, advisories, and guidance	Magnitude of residual risk Adequacy of controls Reliability of controls	Treatment process used and materials treated Amount of hazardous materials destroyed or treated Degree of expected reductions in toxicity, mobility, and volume Degree to which treatment is irreversible Type and quantity of residuals remaining after treatment	Protection of community during remedial actions Protection of workers during remedial actions Environmental impacts Time until remedial action objectives are achieved	Ability to construct and operate the technology Reliability of the technology Ease of undertaking additional remedial actions, if necessary Ability to monitor affectiveness of remedy Ability to obtain approvals from other agencies Coordination with other agencies Availability of offsite treatment, storage, and disposal services and capacity Availability of necessary equipment and specialists Timing of new technology under consideration	Capital costs Operating and maintenance costs Present worth costs	Support agency dependent	Community dependent

requires selecting a "remedial action that is protective of human health and the environment."[3] Review of the alternatives under this criterion essentially involves a composite assessment of the alternative against several of the other evaluation criteria, especially long-term effectiveness and permanence, short-term effectiveness, and compliance with ARARs.[4]

2. Compliance with applicable or relevant and appropriate requirements. As described in Chapter 3 of this feasibility study, compliance with ARARs or the appropriate invocation of a waiver for ARARs is also a minimum or threshold criterion under Superfund.[5] Appendix B of the feasibility study lists all ARARs identified by the Montana Department of Health and Environmental Sciences and the USEPA for the Warm Springs Ponds Operable Unit. Chapter 3 further refines this identification, and provides a list of the most significant ARARs. This chapter identifies those ARARs most significant to each alternative and identifies whether the alternative is expected to comply with these ARARs. Table 8-4 provides a summary of compliance with federal and Montana ARARs. Since none of the alternatives are expected to meet the arsenic and mercury ambient water quality standards, the analysis of ARARs compliance throughout this chapter assumes that a technical impracticability

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3 CERCLA § 121(b)(1) and (d)(1), 42 USC §§ 9621(b)(1) and (d)(1). Also USEPA, 1988, 6-5 and 6-6.

4 USEPA, 1988, 6-5, 6-6.

5 CERCLA § 121(d)(2)(A), 42 USC § 121(d)(2)(A). Also Ibid. 6-5.

Table 8-4
ALTERNATIVE DESIGN
COMPLIANCE SUMMARY FOR FEDERAL AND MONTANA ARARs

ARAR Subject	Montana Statutory/ Regulatory Section	Description of Provision	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6	Alternative 7
Surface Water	ARM16.20.622	Ambient surface water quality standards for Montana's C-2 classification	Yes, could treat 4,000 cfs[b]	Yes, could treat 4,000 cfs[b]	Yes[c]	Yes[c]	No[d]	No[d]	No[e]
	ARM16.20.622	Waste treatment requirements for point source discharges to receiving waters	Yes, could treat 4,000 cfs[b]	Yes, could treat 4,000 cfs[b]	Yes[c]	Yes[c]	No[d]	No[d]	No[e]
	ARM16.20.203	Maximum contaminant levels for inorganic chemicals in potential community water systems	Yes, could treat 4,000 cfs[b]	Yes, could treat 4,000 cfs[b]	Yes[c]	Yes[c]	No[d]	No[d]	No[e]
	40 CFR 122-125	NPDES monitoring requirements	Yes	Yes	Yes	Yes	Yes	Yes	No
	40 CFR 125.130(b)	Best Management Practice	Yes	Yes	Yes	Yes	Yes	Yes	No
	40 CFR Parts 230 and 231	Dredge and fill requirements	Yes	Yes	Yes	Yes	Yes	Yes	NA[f]
Air	ARM16.8.815	Montana air standard for lead	Yes	Yes	Yes	Yes	Yes	Yes	NA
	ARM16.8.818	Montana particulate air standard	Yes	Yes	Yes	Yes	Yes	Yes	NA
	ARM16.8.821	Montana PM-10 standard	Yes	Yes	Yes	Yes	Yes	Yes	NA
	ARM16.2.1401(4)	Montana 20% opacity standard	Yes	Yes	Yes	Yes	Yes	Yes	NA
	40 CFR Part 50	National primary and secondary ambient air quality standards	Yes	Yes	Yes	Yes	Yes	Yes	No
	40 CFR Part 61	National emission standards for hazardous air pollutants	Yes	Yes	Yes	Yes	Yes	Yes	No
Groundwater	ARM16.20.1003	Montana Class II groundwater quality standards	Yes	Yes	Yes	Yes	Yes	Yes	No
Floodplain Management	ARM36.15.606	Criteria for flood control works allowed within designated floodways	Yes	Yes	Yes	Yes	No	No	No

ARAR Subject	Montana Statutory/ Regulatory Section	Description of Provision	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6	Alternative 7
	ARM36.2.404	Evaluation criteria for Natural Streambed and Land Preservation Act (1975) standards and guidelines	Yes	Yes	Yes	Yes	Yes	Yes	No
	40 CFR 6 (App. A) Exec. Order 11,988	Floodplains Management	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	40 CFR 6 (App. A) Exec. Order 11,990	Protection of Wetlands	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Dam Safety	ARM36.14.501	Design criteria for high hazard dams	Yes	Yes	Yes	Yes	Yes	Yes	NA
	ARM36.14.502	High hazard dam inflow deaign criteria	Exceeds ARAR	Exceeds ARAR	Yes	Yes	Yes	NA	NA
Reclamation	ARM26.4.505	Requires adequate cover over waste materials to prevent salt migration, adverse plant effects, and water pollution	Yes	Yea	Yes	Yes	Yes	Yes	No
	ARM26.4.520	Criteria for disposal of soil materials (tailings and contaminated soils)	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	ARM26.4.633	Requires that all surface drainage from disturbed areas be treated by the best available technology	Yes	Yes	Yes	Yes	Yes	Yes	No
	ARM26.4.642	Permanent impoundment construction and operation requirements	Yes	Yea	Yes	Yes	Yes	NA	NA
	ARM26.4.711	Revegetation actions must establish a diverse, effective, and permanent cover capable of self-regeneration and plant succession	Yes	Yes	Yes	Yes	Yes	Yes	NA
Hazardous Waste	ARM16.4.701-ARM16.4.703	Incorporation of federal regulatory requirements that establish the standards for permitted hazardous waste management facilities	Yes	Yes	Yes	Yes	Yes	Yes	No
Solid Waste	ARM16.14.505	Siting criteria for solid waste disposal disposal sites	Yes	Yes	Yes	Yes	Yes	Yes	No
	40 CFR Part 257	Criteria for solid waste classification and disposal	Yes	Yes	Yes	Yes	Yes	Yes	No

ARAR Subject	Montana Statutory/ Regulatory Section	Description of Provision	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6	Alternative 7
Occupational Safety	29 USC 651-678	Occupational Safety and Health Act	Yes	Yes	Yes	Yes	Yes	Yes	No
Historic Preservation	16 USC 469 40 CFR 6.301(c)	Archaeological and Historic Preservation Act	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	16 USC 470 40 CFR 6.301(b) 36 CFR Part 800	National Historic Preservation Act	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	16 USC 461-467 40 CFR 6.301(a)	Historic Sites, Buildings, and Antiquities Act	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	16 US 1531-1566 40 CFR 6.302(g)	Fish and Wildlife Coordination Act	Yes	Yes	Yes	Yes	Yes	Yes	No
Natural Resource	16 USC 1531-1543 50 CFR Parts 17 & 402 40 CFR 6.302(h)	Endangered Species Act	Yes	Yes	Yes	Yes	Yes	Yes	No
	40 CFR 6(App.A)	Protection of Wetlands	Yes	Yes	Yes	Yes	Yes	Yes	No

[a] ARAR compliance indicates that the requirements stated will be met with the exception that ambient water quality standards for arsenic and mercury will not be met under any alternative and will require a waiver based on technical impracticability, as discussed in Chapter 8.
[b] 4,000 cfs is a 100-year flood event on Silver Bow Creek
[c] Alternatives 3 and 4 could treat pond in-flows up to 600 cfs. This magnitude of flow is expected to be exceeded once every 2 years.
[d] Alternatives 5 and 6 could treat pond in-flows up to 210 cfs. This magnitude of flow is expected to be exceeded once each year.
[e] Current operating procedures result in the exceedance of water quality standards about 40 percent of the time.
[f] NA = not applicable.

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waiver will be applied in the Record of Decision.[6] Decisions to apply waivers, if any are required, will be made during the Record of Decision (ROD) process.

3. Long-term effectiveness. Superfund requires selection of a remedial action that uses permanent solutions to the maximum extent practicable.[7] It also requires that long-term effectiveness of the various alternatives[8] be addressed prior to remedy selection. Evaluation of the alternatives in relation to this criterion involves assessing the adequacy and reliability of the controls selected to manage treatment residuals and/or untreated wastes, and evaluating the magnitude of residual risks remaining to human health and the environment after the remedy has been implemented.[9]

4. Reduction of toxicity, mobility, volume, persistence, and propensity to bioaccumulate. Superfund prefers selection of remedial actions that, through treatment, permanently and significantly reduce the "volume, toxicity or mobility of the hazardous substances, pollutants, and contaminants."[10] It also requires assessment of the persistence of the hazardous substances and their propensity to bioaccumulate.[11]

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6 CERCLA § 121(d)(4), 42 USC § 9621(d)(4); see also, discussion of ARAR waivers in Chapter 3 of this feasibility study.

7 CERCLA § 121(b)(1), 42 USC § 9621(b)(1).

8 Id.

9 USEPA, 1988. 6-8.

10 CERCLA § 121(b)(1), 42 USC § 9621(b)(1).

11 CERCLA § 121(b)(1)(C), 42 USC § 9621(b)(1)(C).

5. Short-term effectiveness. This criterion examines the short-term potential for adverse health effects from human exposure[12] and adverse environmental effects that may occur during the implementation phase of the remedial action alternative.[13]

6. Implementability, reliability, and constructibility. Federal regulations require an assessment of an alternative's implementability, reliability, and constructibility from an engineering perspective.[14] Additionally, USEPA requires consideration of implementability from an administrative perspective (e.g., coordination with other agencies such as obtaining permits for offsite activities or rights-of-way for construction).[15]

7. Cost. In addition to the other requirements, Superfund requires selection of a cost-effective remedy, including consideration of long-term operation and maintenance costs.[16] USEPA guidelines recommend that costs be developed with an accuracy of plus 50 percent to minus 30 percent.[17] Cost estimates developed in the detailed analysis include both capital costs and annual costs. Capital costs include both direct and indirect costs, including construction, nonconstruction, and

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12 CERCLA § 121(b)(1)(D), 42 USC § 9621(b)(1)(D).

13 USEPA, 1988. 6-9.

14 40 CFR § 300.68(h)(2)(iii)

15 USEPA, 1988. 6-9 to 6-11.

16 CERCLA § 121(b)(1) and (b)(1)(E), 42 USC § 9621(b)(1) and (b)(1)(E); 40 CFR § 300.68(h)(2)(ii).

17 USEPA, 1988. 6-12.

overhead. Annual costs are those necessary to ensure the continued effectiveness of the remedial action following construction, including operation, maintenance, insurance, taxes, administrative, disposal, rehabilitation, and periodic site review costs.[18] All future costs are reduced to present worth costs to allow remedial action alternative costs to be compared on a relatively equivalent basis. Present worth costs are determined by an analysis that evaluates expenses over time by discounting future costs to a common base year. Appendix D contains detailed cost tables for each alternative.[19]

In addition to the evaluation criteria established by the USEPA, Superfund also requires the use of "alternative treatment technologies" and "resource recovery technologies to the maximum extent practicable."[20] Instances in which remedial actions incorporate the use of alternative treatment technologies or resource recovery technologies (e.g., recycle/reuse, waste minimization, and waste biodegradation) are, therefore, identified as part of the detailed (individual) analyses.

The evaluation in this chapter relies on the detailed development of the media-specific actions as set out in Chapter 7. The detail for alternatives at this stage is at a conceptual design, not a full design, level. Design details and cost

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18 Id. 6-11 and 6-12.

19 See also USEPA, 1985. Remedial Action Costing Procedure Manual.

20 CERCLA § 121(b)(1), 42 USC § 9621(b)(1); see also 40 CFR § 300.68(h)(2)(v).

estimates will continued to be refined following selection of an alternative and ultimately up until final implementation of the remedial action.

This chapter concludes with a comparative analysis of the alternatives in which the strengths, weaknesses, and trade-offs of each alternative are presented as they are again evaluated against the first seven USEPA evaluation criteria. The process of analyzing each alternative against specific evaluation criteria and then comparatively analyzing the alternatives against one another is designed to provide sufficient information to enable state and USEPA decisionmakers to adequately compare alternatives, select an appropriate remedy for the site, and demonstrate that the selected alternative satisfies statutory and regulatory requirements.[21]

INDIVIDUAL ANALYSIS OF ALTERNATIVES

This section provides an analysis of each of the alternatives against the seven evaluation criteria listed above. Each analysis starts with a short description of the alternative being considered, followed by a criterion-by-criterion critique of the alternative. The first two criteria, overall protectiveness and compliance with ARARs, are addressed in terms of the overall comprehensive alternative. The remaining five criteria are addressed in terms of the separate components. For media-specific actions that appear in more than one alternative, the analyses of the five balancing criteria are included with the first alternative

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21 USEPA, 1988. 6-3.

in which the action appears. It is then referred to in subsequent analyses.

The results of the analyses are summarized in Table 8-5.

ALTERNATIVE 1: EXCEEDS THE REQUIREMENTS OF ARARs

Alternative 1 was developed to be the most comprehensive of the alternatives. It is one of two alternatives expected to exceed the requirements of a significant ARAR by protecting the pond bottom sediments against a PMF. The components of Alternative 1 include:

- Solidification of all onsite contaminated soils, tailings, and sediments (the tailings deposits and contaminated soils would be excavated and moved into one of the ponds prior to solidification)

- Construction of a new treatment pond for surface water treatment and an upstream flood impoundment to capture flood flows for subsequent treatment

- Installation of a trench to capture contaminated groundwater as it migrates away from the ponds

These components are listed in greater detail in Table 8-2.

Overall Protection of Human Health and the Environment

Alternative 1 addresses all of the identified risks to human health and the environment present at the site using

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Table 8-5
SUMMARY OF INDIVIDUAL ANALYSIS OF ALTERNATIVES

Criteria	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6	Alternative 7
Description	Solidify pond sediments; remove soils from bypass; construct a new treatment pond and s flood impoundment of 8,000 acre-feet; excavste contaminated soil with pond disposal and solidification; groundwater collection with treatment in new pond.	Stabilize pond berms against PMF and MCE; remove soils from bypass; upgrade trestment system; add flood impoundment of 8,000 acre-feet; excavate contaminated soil with offsite dispossl; groundwater collection with treatment in Pond 3.	Stabilize pond berms against a partial PMF and the MCE; remove soils from bypass; upgrade treatment system; add settling basin of 2,000 acre-feet; excavate contaminated soil with Pond 1 disposal; cap Pond 1; groundwater collection with treatment in Pond 3.	Stabilize pond berms against a partial PMF and the MCE; remove soils from bypass; upgrade treatment system; add settling basin of 2,000 acre-feet; cap and revegetate contaminated soil; groundwster collection with treatment in Pond 3. Flood Pond 2.	Stabilize pond berms against a partial PMF and the MCE; remove soils from bypass; modify treatment system; add settling basin of 2,000 acre-feet; cap snd revegetate contaminated soils; groundwater collection with wetlands treatment.	Stsbilize pond berms against a partial PMF and the MCE; remove soils from bypass; modify trestment system; flood contaminated soils and cap Pond 1; groundwater collection with wetlands trestment.	No action.
Overall Protectiveness							
Pond Bottom Sediments	Risks reduced through solidification of sludges and sediments.	Risks reduced through stabilization of pond berm against threat of failure.	Risks reduced through stabilization of pond berms against moderate cases.	Same as Alternative 3.	Same as Alternative 3.	Same as Alternative 3.	No reduction in risk; threat of pond failure increases with time.
Surface Water	New treatment pond and flood impoundment pond would provide improved water quality through enhanced treatment for all flows.	Upgraded treatment and flood impoundment pond would provide improved water quality through enhanced treatment for all flows.	Upgraded treatment pond and new settling pond would provide improved water quality. All flows less than 600 cfs and the first 2,000 acre-feet of flows greater than 600 cfs treated for suspended and dissolved metals. Remaining flows treated for suspended solids only.	Same as Alternative 3.	Modified treatment system and new settling pond would provide improved water quality for up to 210 cfs and the first 2,000 acre-feet of flows greater than 210 cfs. Flows above 120 cfs treated for suspended solids only.	Modified treatment system would provide improved water quality for up to 210 cfs. Only flows less than 210 cfs receive treatment.	No improvement in water quality. Frequent violations and periodic fishkills.
Tailings Deposits and Contaminated Soils	Risks reduced through excsvation and solidification.	Risks reduced through excavation and offsite disposal at a RCRA TSDF. No treatment prior to disposal.	Risks reduced through excavation and disposal under a RCRA-equivalent cap. No treatment prior to disposal.	Risks reduced through capping in place and excavation with onsite disposal under a cap. Inherent risk of capping material in a flood plain exists below Pond 1. No treatment prior to capping.	Same ss Alternative 4.	Some reduction in risks through flooding in place and excavation with onsite disposal under a cap. No treatment prior to flooding or capping.	No reduction in risk of migration or exposure.

Table 8-5 (continued)

Criteria	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6	Alternative 7
Groundwater	Collection with treatment in a new treatment pond reduces risk of exposure and migration.	Collection with treatment in Pond 3 reduces risk of exposure and migration.	Same as Alternative 2.	Same as Alternative 2.	Collection with onsite wetlanda treatment reduces risk of exposure and migration in groundwater, but increases risk of contamination of wetlands biota, sediment, and soils.	Same as Alternative 5.	No reduction in risk of migration or exposure.
Compliance with ARARs							
Chemical-specific, Location-specific, and Action-specific	See Table 8-4.	See Table 8-4.	See Table 8-4.	See Table 8-4.	See Table 8-4.	See Table 8-4.	See Table 8-4.
Long-Term Effectiveness and Performance							
Residual Risk	All present risks reduced; residual risks result from deposition of tailings and sludges in the new treatment and flood impoundment ponds.	All present risks addressed; residual risks result from unsolidified sludges in Ponds 1 and 2, and the continued deposition of tailings and sludges in the flood impoundment and Pond 3.	All present risks addressed; residual risks result from extreme floods, unsolidified sludges in Pond 2, capped sludges in Pond 1, the continued deposition of tailings and sludges in the settling basin and in Pond 3, and the discharge without dissolved metals treatment of flows greater than 600 cfs and 2,000 acre-feet.	All present risks addressed, reaidual risks result from extreme flooda, unsolidified aludges in Pond 2, capped sludges in Pond 1, the continued depoaition of tailings and sludges in the settling bsin and in Pond 3, large quantity of capped material around the site, and the discharge without dissolved metals treatment of flows greater than 600 cfs and 2,000 acre-feet.	All present risks addressed; residual risks result from extreme floods, unsolidified sludges, continued use of Pond 2 during high flows, continued deposition of tailings and sludges in Pond 3 and tailings in the settling pond, large quantity of capped material around the site, and the discharge without dissolved metals treatment of flows greater than 210 cfs and 2,000 acre-feet.	Majority of present risks addressed; residual risks result from lack of treatment for flows greater than 210 cfs, threat of extreme floods, unsolidified sludges, continued use of Pond 2, continued deposition of tailings and sludges in Pond 3, and lack of containment on flooded soils and tailings.	All present risks remain unmitigated.

Table 8-5 (continued)

Criteria	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6	Alternative 7
Adequacy and Reliability of Controls	In situ solidification of sludges is unproven and because of sludge volume, solidification could take up to 14 years. Remaining controls are adequate to manage risks and are reliable with proper design, construction, operation, and maintenance.	All controls adequate and reliable for stated purpose. O&M required to maintain reliability.	All controls adequate and reliable for stated purpose. O&M required to maintain reliability.	Same as Alternative 3.	Wetlands treatment of extracted groundwater is an innovative, underdeveloped process. The adequacy and reliability of wetlands treatment cannot be stated with certainty. Other controls are adequate and reliable for their stated purpose. O&M required to maintain reliability. Modifications to pond treatment system may not be adequate to consistently achieve discharge standards.	Same as Alternative 5.	Inadequate to achieve remedial action objectives for the operable unit.
Reduction of Toxicity, Mobility, and Volume	Solidification of sludges directly reduces mobility of pond bottoms. New treatment ponds reduce toxicity of surface water. Excavation and solidification of soils and tailings reduces mobility. Groundwater collection and treatment reduces mobility and toxicity.	Stabilization of pond berms reduces mobility of pond bottoms for all cases. Upgraded treatment system and flood impoundment reduce toxicity of surface water. Excavation and offsite disposal of soils and tailings reduces their mobility. Groundwater collection and treatment reduces toxicity.	Stabilization of pond berms reduces mobility of pond bottoms for all but extreme cases. Upgraded treatment system and settling basin reduce toxicity of surface water. Excavation and onsite disposal of tailings reduces their mobility. Groundwater collection and treatment reduces mobility and toxicity.	Stabilization of pond berms reduces mobility of pond bottoms for all but extreme cases. Upgraded treatment system and settling basin reduce toxicity of surface water. Groundwater collection and treatment reduces mobility and toxicity. Capping tailings in place will reduce their mobility except in cases of extreme mobility.	Stabilization of pond berms reduces mobility of pond bottoms for all but extreme cases. Modified treatment system and settling basin reduces toxicity of surface water. Capping tailings in place will reduce their mobility. Groundwater collection and treatment in wetlands reduces mobility and toxicity of groundwater, but increases toxicity of wetland biota, sediment, and soils and may result in recontamination of groundwater.	Stabilization of pond berms reduces mobility of pond bottoms for all but extreme cases. Modified treatment system reduces toxicity of surface water. Flooding tailings in place will reduce their direct mobility. Groundwater collection and treatment in wetlands reduces toxicity of groundwater, but increases toxicity of wetland biota, sediment, and soils.	No reduction of toxicity, mobility, or volume.

Table 8-5 (continued)

Criteria	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6	Alternative 7
Short-Term Effectiveness							
Protectiveness	No increased risk to community during remediation. Protection of workers against dermal contact and inhalation of tailings dust required in tailings contaminated areas.	Same aa Alternative 1.	Same as Alternative 1.	Same aa Alternative 1.	Same as Alternative 1.	Same as Alternative 1.	Threat of pond failure increases with time. Other risks remain unchanged.
Environmental Impacts	Significant habitat alteration due to pond solidification and construction of new ponds. 1,200 acres of wetlands and open water habitat destroyed. Up to 600 acres of open water habitat created by new treatment pond. Potential for airborne release of tailings during implementation. Upstream flood impoundment will permanently alter up to 1,000 acres of rangeland. Planning required to prevent affecting a pair of bald eagles sighted within the operable unit. Solidification would remove 1,000 acres of eagle feeding area.	Some temporary habitat alteration will occur during remediation. Only the upstream flood impoundment and capping Pond 1 will permanently alter up to 1,000 acres of rangeland. Potential for airborne release of tailings during implementation. Treatment of bypass flows in the pond system will dry up a portion of the bypass during all flows less than a 100-year flood (up to 4,000 cfs, eliminating an established catch and release fishery. Planning required to prevent affecting a pair of bald eagles sighted within the operable unit.	Same aa Alternative 2, except upatream settling basin will alter aignificantly lesa rangeland (500 acrea va. 1,000 acrea) than the flood impoundment. Planning required to prevent affecting a pair of bald eagles sighted within the operable unit.	Some temporary habitat alternation will occur during remediation. Upatream aettling baain will permanently alter up to 500 acrea of rangeland. Potential for airborne release of tailings during implementation. Treatment of bypass flowa in the pond system will dry up a portion of the bypaas during all flowa lesa than 600 cfs, eliminating an established fishery. Planning required to prevent affecting a pair of bald eagles sighted within the operable unit.	Same as Alternative 4, except the bypasa will only be affected during flows of lesa than 210 cfa or above 210 cfa but under 2,000 acre-feet. Planning required to prevent affecting a pair of bald eagles sighted within the operable unit.	Same as Alternative 5, except there would be no impact on rangeland due to no upstream settling basin. Planning required to prevent affecting a pair of bald eagles sighted within the operable unit.	Continued impacts from existing conditions.
Time Until Completion	Approximately 17 years	Three to four construction seasons.	Two to three construction seasons.	Same as Alternative 3.	Two to three construction seasons to complete. Startup of wetlands system may take 5 years.	Same as Alternative 5.	Not applicable.

Table 8-5 (continued)

Criteria	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6	Alternative 7
Implementation, Reliability, Constructibility							
Ability to construct and operate	In situ solidification process is an innovative technology with no past remediation experience. The effectiveness of the process for remediation is unknown. It has been used in Japan for swamp stabilization. Other components are feasible, implementable, and reliable for their stated objective. Land acquisition for the flood impoundment may prove difficult.	All components are feasible, implementable, and reliable for their stated objective. Availability of adequate riprap is unknown. Land acquisition for the flood impoundment may prove difficult.	Same as Alternative 2, except land acquisition for settling basin may prove less difficult than for the flood impoundment.	Same as Alternative 3.	Wetlands treatment system is an innovative technology. It has been used with varying degrees of success. May require extensive startup time. Long-term reliability cannot be fully assessed. All other components are feasible for their stated objective. Availability of adequate riprap is unknown. Land acquisition for the settling basin may prove difficult.	Same as Alternative 5, except there is no land acquisition required.	Not applicable.
Permits Required	MPDES permit required for pond discharge.	Same as Alternative 1.	Same as Alternative 1.	Same as Alternative 1.	Same as Alternative 1.	Same as Alternative 1.	Same as Alternative 1.
Monitoring Requirements	Surface water and groundwater monitoring required for compliance.	Same as Alternative 1.	Same as Alternative 1.	Same as Alternative 1.	Same as Alternative 1.	Same as Alternative 1.	Ongoing surface water monitoring as required per MPDES permit.
Costs							
Capital	$1,679 million	$261 million	$71 million	$78 million	$66 million	$55 million	--
Annual O&M	$283,000	$301,000	$300,000	$293,000	$284,000	$270,000	--
Present Worth	$1,191 million	$241 million	$71 million	$77 million	$66 million	$55 million	--

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measures designed to control or eliminate the risks to the maximum extent possible.

The current inability of the three existing ponds to withstand expectable floods and earthquakes would be addressed using an in situ solidification process to stabilize in place the pond bottom sludges and sediments of each pond. This would minimize the risk of pond failure due to an earthquake or flood event by permanently solidifying the sediments. A new treatment pond capable of treating the current level of contaminated influent surface water for a period of up to 100 years would be constructed upstream of Pond 3 to provide continuing treatment for the contaminated surface water flowing through the site.

Alternative 1 would improve surface water quality for all flows by removing tailings from along the bypass and constructing a new pond treatment system and an upstream flood impoundment. Flows of surface water up to the volume of a 100-year flood (8,000 acre-feet) would be detained in the flood impoundment and treated in the new pond, which would be designed to provide more effective and more consistent treatment than the current pond system. With the new treatment system and the upstream flood impoundment, discussed immediately below, surface water quality violations should be avoidable, except during floods with flow rates exceeding the theoretical maximum flow of a 100-year flood in Silver Bow Creek (4,000 cfs).

During flood flows between 600 and 4,000 cfs on Silver Bow Creek, the untreated surface water would be temporarily detained in a new upstream flood impoundment and released

for additional treatment at the design limit of the new pond (600 cfs). The flood impoundment would be of adequate capacity to contain the volume of up to a 100-year flood (see Chapter 7) and release it slowly (less than 500 cfs) for treatment in the new pond. During floods exceeding the capacity of the flood impoundment, a portion of the flood would be routed around the impoundment to protect the impoundment from damage due to overfilling. The majority (approximately 80 percent by weight) of suspended solids would settle out of the contained flow in the impoundment prior to its release. The flow equalization capacity provided by the impoundment would allow for downstream pond treatment of flood flows for dissolved metals contaminants in all flows except those with volumes greater than 100-year floods. Use of the flood impoundment would reduce the potential for recontamination of the bypass by settled tailings and the continued transport of tailings into the Clark Fork Basin.

Contaminated groundwater moving from the operable unit would be collected from in and below Pond 1. It would then be pumped to the inlet of the new pond for treatment. This would reduce the discharge of contaminated groundwater into the Clark Fork River and result in the groundwater downgradient of Pond 1 meeting the Montana groundwater requirements identified in Chapter 3 (primary MCLs).

Excavating the contaminated soils and tailings deposits with arsenic concentrations above the assumed action level of 250 ppm and/or lead concentrations above the assumed action level of 750 ppm, and disposing of them in the existing ponds prior to solidification, would permanently reduce the

mobility of the tailings. It would also effectively reduce the potential for future human or animal contact with the materials.

This alternative would, with the appropriate design, construction, and maintenance, reliably reduce the risks for which it is proposed. Because of the enormous volume of pond sludges (19 million cubic yards), in situ solidification would take approximately 14 years to complete. Full risk reduction, especially risks from floods and earthquakes, would not occur until approximately 17 years from project initiation. Increased risks to the surrounding environment and community during implementation of the alternative would be manageable, with proper safety and construction practices.

Compliance with ARARs

Within the conditional boundaries established below, Alternative 1 should result in compliance with all the state and federal ARARs identified for the operable unit.

Solidifying the tailings and contaminated soils in the three existing ponds would exceed the requirements of the Montana ARARs for protection against flooding by protecting the pond bottom sediments against a PMF. This would also result in compliance with earthquake ARARs (protection against an MCE). Constructing an 8,000 acre-foot flood impoundment, removing tailings, sediments, and soils, and developing a new pond treatment system should result in compliance with state and federal ambient and point source discharge surface water quality standards for flows up to a 100-year flood event and state requirements for floodplain management. The proposed solidification and capping of the existing ponds

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would comply with the siting criteria for solid waste disposal and would satisfy pertinent RCRA requirements for closure of hazardous waste management facilities. Pumping and treating groundwater would result in compliance with Montana groundwater standards (primary MCLs). Table 8-4 presents a summary of this alternative's compliance with all ARARs identified by the MDHES and the USEPA.

The actions proposed in Alternative 1 could result in adverse effects on wetlands, endangered species and historical resources. To mitigate these potential impacts, consultation with state and federal agencies will be required.

Long-Term Effectiveness

Alternative 1 addresses each of the identified risks at the site with measures intended to limit or remove the risk. The residual risk following implementation of this alternative would be lower than for any of the other six alternatives. The most significant long-term risks would result from the accumulation of treatment residuals in the new treatment pond and sediments in the upstream flood impoundment. Periodic (5-year) reviews of risks resulting from contamination in the two new ponds would be necessary.

Following implementation, the two new ponds and the groundwater collection system would require regular operation, maintenance, and monitoring in order to meet the design/performance specifications. These tasks would include maintaining feed stocks in the lime system, performing routine maintenance for the groundwater pumps, the lime system, and the mechanical parts of the upstream flood impoundment, and conducting compliance monitoring for the treatment pond.

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Operational problems for the treatment pond and the groundwater system could be minimized by utilizing the standard practice of 100 percent redundancy on major mechanical parts. Any operational problems experienced with the flood impoundment could result in the release, without treatment, of flows greater than the design flow of the treatment pond (600 cfs); these flows would be diverted around the treatment pond by its inlet structure.

Reduction of Toxicity, Mobility, Volume, Persistence, and Propensity to Bioaccumulate

One of the major components of Alternative 1 is the solidification of all contaminated soils, tailings, sediments, and sludges with concentrations of arsenic or lead above the assumed action levels. Stabilization of this material, especially the 19 million cubic yards of pond bottom sediments, would remove the principal threat at the site (the mobility of these metals-contaminated materials). The in situ solidification process is permanent and irreversible, but it would not reduce the volume of contaminated material at the site. Rather, an approximately three-fold increase in volume could occur due to the addition of large quantities of solidification agents.

The remaining components of Alternative 1 address the toxicity of the surface waters and groundwater at the site. The groundwater from in and below Pond 1 and the surface waters entering the site would be treated for dissolved metals to meet the water quality standards. Because the water in the bypass would be directed into the treatment pond, all of the stream flows entering the operable unit (Silver Bow, Mill, and Willow Creeks) would receive treatment. The upstream flood impoundment would both remove suspended solids and

detain flows between 600 cfs (the treatment pond's design maximum flow for treatment) and 4,000 cfs (the theoretical maximum 100-year flood flow rate). Consequently, contaminated surface water entering the site would be treated in all but extreme cases for suspended solids and for dissolved metals to achieve compliance with the water quality standards.

Because of the ongoing treatment of surface water and groundwater, metal sludges and sediments would, over time, deposit on the bottom of the new treatment pond. The sludges in the treatment pond would be submerged and would only pose a threat in the event of a failure of the pond. In the flood impoundment, the settled material would not always be covered with water, similar to the tailings deposits settled along the bypass. They would therefore result in similar risks, especially the risk of fishkills. To reduce the risk from this material, it could be removed after high flow events (routed through the pond) and disposed of either offsite or in the new treatment pond. Alternatively, it might be possible to design the impoundment not to require cleaning after every flood event.

Short-Term Effectiveness

Because of the volume of tailings, soils, and sludge at the site, it is expected that completion of the Alternative 1 components would take approximately 17 years. Overall protection of the downstream environment would not be attained until the complete alternative had been completed. However, as the process progressed, the degree of protectiveness would increase. The solidification process would not increase the risks to the community as long as institutional controls were applied to limit access during construction.

Because of the threats of ingestion, inhalation, and dermal contact, remediation workers would be required to use appropriate protective equipment. Remaining risks to the remediation workers relate to standard construction risks. They would be addressed using standard construction safety practices.

Adverse environmental impacts resulting from the implementation of Alternative 1 would be substantial from destruction of large areas of existing wildlife habitat. Excavation of contaminated soils and tailings would eliminate a wetland area below Pond 1; and solidification of Ponds 1, 2, and 3 would destroy over 1,200 acres of wetland and open water habitat for birds, fish, and mammals. Following solidification, the area would be returned to wildlife habitat as dry, vegetated land, unsuitable for the same wildlife populations.

The removal of tailings and contaminated soils from along the bypass may adversely affect water quality during remediation. However, the majority of adverse affects could be avoided by use of appropriate temporary sediment control measures, such as settling basins. Risks to the surrounding communities from dust generation would be minimized by use of appropriate dust control measures during excavation activities. The inhalation and dermal risk to remediation contractors can be controlled using protective equipment. This work would take 1 to 2 years to complete.

The construction of the new treatment pond and the flood impoundment proposed for Alternative 1 would take at least two construction seasons, but during that period the current

treatment of the contaminated surface waters would be continued. Both new ponds would be constructed offline and would not affect the water quality downstream until complete. Until that time, the risk to the environment and downstream communities would remain at the current level described in the Public Health and Environmental Assessment (PHEA) (Appendix A). The new treatment pond would be constructed in a contaminated area requiring protective equipment for workers. The flood impoundment would be constructed in an upstream, uncontaminated area, and the risks to the workers involved in remediation would be similar to that of workers during standard construction of similar facilities. Some of the inlet structures for the flood impoundment would be constructed in contaminated areas requiring protective equipment for workers. A long-term environmental impact of constructing the flood impoundment would be the removal of approximately 1,000 acres of land from use.

Measures to construct new wetland areas may be required in order to preserve the existing total amount of wildlife habitat.

Planning for all remediation activities would have to consider potential impacts to a pair of bald eagles, protected under the Endangered Species Act, which have previously nested within the operable unit. The eagles have also been observed using the ponds as a source of food. However, during winter months when the ponds freeze over, the eagles were noted to have moved into the Clark Fork basin. Solidification would permanently remove the ponds as a source of food for the eagles, but the impacts should be minimal with the continued availability of local creeks and the entire Clark Fork basin. If the eagles return to nesting within

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the ponds area, remediation activities would need to be scheduled to minimize impacts (e.g., during winter months). With attention to the necessary controls, adverse impacts to the eagles can likely be avoided.

The remediation schedule for Alternative 1 is shown in Figure 8-1.

Implementability, Reliability, and Constructibility

The in situ solidification process proposed for Alternative 1 has been used with success in Japan for airport construction in marshy areas, but it is relatively new both in the U.S. and in hazardous site remediation. Consequently, the ability of the technology to adequately stabilize the contaminated material in the ponds cannot be stated without qualification. Ineffective stabilization or incomplete mixing of the solidification agent with the sediment are two concerns that would need to be addressed during design and construction. The effectiveness of the process would be investigated using standard coring techniques to take samples of the stabilized material. Should the process fail to adequately stabilize the pond sludges, the existing pond berms would have to be protected against failure, as described in Alternatives 2 and 3. Should the process fail to sufficiently limit the mobility of the metals contained in the sludges (i.e., if leaching occurs), a surface cap would be necessary to limit water infiltration and leaching of metals from the stabilized sediments.

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TASK DESCRIPTION	1st YEAR												2nd YEAR												3rd YEAR												4th YEAR												5th YEAR											
	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
Design Investigations	—	—	—	—	—	—	—	—	—	—	—	—																																															
Remediol Design	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—																																					
Lond Acquisition	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—																									
Permitting for Materiols Quarries	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—																									
Advertising, Bidding, and Aword	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—																									
Stobilize/Solidify Sediments																																																									
Monufocture Machines	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—																									
Stobilize/Solidify Pond Sediments	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Through
Remove ond Dispose of Contominated Soils Along Mill-Willow Bypass	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—																								Year 17
Construct New Treotment Pond																																																							
Roise/Construct Berms	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—																									
Improve Inlet Structure	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—																									
Install Lime Treotment Facility	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—																									
Construct Flow Control Structures	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—																									
Construct Upstreom Impoundment																																																							
Relocote Power Lines	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—																									
Construct Berms	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
Construct Diversion Dam	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
Construct Flow Control Structures	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
Groundwater Collection Below Pond 1 with Treatment in Pond 3																																																							
Construct Groundwater Drains	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—																									
Install Pipeline to New Treatment Pond	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—																									
Install Pump Station	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—																									

FIGURE 8-1

ESTIMATED PROJECT SCHEDULE
FOR ALTERNATIVE 1
WARM SPRINGS PONDS OUFS

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The remaining components of Alternative 1--the new ponds and the groundwater interceptor drains--involve standard construction practices that are known to be technically feasible. Construction of these components should not pose a great difficulty. One potential problem, however, concerns the attainment of water quality standards for aquatic life and public health in the effluent from the new pond. Variability of the influent and changes in weather can severely affect the quality of the effluent from a pond treatment system. Consequently, consistent attainment of the design discharge limits may require fine tuning of operation practices or upgrading the treatment system beyond the scope of the conceptual design.

There are three administrative feasibility concerns associated with Alternative 1. They involve the destruction of wetland and open water wildlife habitat as part of the pond solidification process, land acquisition for the upstream flood impoundment, and the discharge permit requirements for releasing treatment pond effluent. Currently, the entire Warm Springs Ponds site is managed as a wildlife refuge by the Montana Department of Fish, Wildlife, and Parks. Stabilization of the ponds and the construction of a new pond would substantially alter the site, permanently destroying over 1,200 acres of wetland and open water wildlife habitat, including a substantial amount of open water used by water fowl and fish. Because of the impact on these habitats, planning for the remediation needs to include consultation with the Department of Fish, Wildlife and Parks, U.S. Fish and Wildlife, USEPA, and the Army Corps of Engineers.

The site's MPDES permit has expired but will continue to be in effect until a remedy is selected for the operable unit. At that time, a new MPDES permit will be required.

All of the materials and services required to implement Alternative 1 are generally expected to be available as needed. The largest quantity of material needed from outside sources will be riprap. If a reliable local source of riprap is not available, it will be quarried near the site specifically for the remediation. Lime for the surface water treatment pond is available from only one source in Montana. This source supplies the lime for the current treatment system and can meet the specifications for the new lime treatment system. The proprietary equipment needed for the pond solidification process could take up to 9 months to fabricate and deliver to the site following contract award. This fabrication time would have to be factored into the remediation schedule.

Cost

Cost evaluations, including the assumptions used, are presented in Appendix D. A summary of the capital costs associated with this alternative are shown in Table 8-6. The costs are order-of-magnitude (+50 percent to -30 percent) estimates. Capital costs are those required to initiate and construct the remedial action. Typical capital costs include construction equipment, labor and materials expenditures, engineering, and construction management. Bid and scope contingencies are also included in the total capital cost.

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Table 8-6
WARM SPRINGS PONDS FEASIBILITY STUDY
COST EVALUATION OF ALTERNATIVES
ALTERNATIVE 1

	Work Item Description	Cost Extensions Including Excess Labor Costs Due to Waste
MSA-2:	Stabilize/Solidity Pond Sediments	$1,243,504,000
MSA-4:	Remove and Dispose of Contaminated Surface Soils Along Mill-Willow Bypass	1,365,000
MSA-5C:	Construct a New Treatment Pond	7,708,500
MSA-6A:	Construct an Upstream Flood Impoundment	19,973,500
MSA-10:	Excavate Tailings Deposits and Contaminated Soils from Areas Below Pond 1; Disposal in Pond 1, 2, or 3	372,000
MSA-12:	Groundwater Collection In and Below Pond 1 With Treatment in Pond 3	1,510,000
Subtotal Alternative 1		**1,274,433,000**
o	Hazardous Waste Protection Costs	13,680,000
		1,288,113,000
o	Division 1 Costs @ 11% of Total[a]	159,205,000
		1,447,318,000
o	15% Contingency	217,098,000
ESTIMATED CONSTRUCTION COST		**$1,664,416,000**
	Engineering Design	4,000,000
	Services During Construction	7,000,000
	Administrative and Legal	3,000,000
TOTAL PROJECT COST		**$1,679,000,000**

[a]Division 1 costs include allowances for general conditions, mobilization, permits, bond, insurance, and winter protection costs.

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Projected annual operation and maintenance costs for Alternative 1 are presented in Table 8-7. These costs are necessary to ensure the continued effectiveness of a remedial action. Included are such items as labor, materials, residue disposal, insurance, taxes, etc.

Table 8-7
ANNUAL OPERATION AND MAINTENANCE COSTS
FOR ALTERNATIVE 1

Description	Annual Cost
Labor and Materials	$ 90,000
Chemicals and Power	120,000
Sampling and Testing	15,000
Equipment Replacement Reserve	48,000
Site Review	10,000
TOTAL	$283,000

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The feasibility level cost estimates shown have been prepared for guidance in project evaluation and implementation from the information available at the time of the estimate. The final costs of the project will depend on actual labor and material costs, actual site conditions, productivity, competitive market conditions, final project scope and schedule, the firm selected for final engineering design, and other variable factors. As a result, the final project costs will vary from the estimates presented here and throughout this feasibility study. Because of these factors, funding needs must be carefully reviewed before making specific financial decisions or establishing final budgets.

Present worth analysis is a method of evaluating expenditures that occur over different time periods. By discount-

ing all alternative costs to a common year (Year 0), the costs for different alternatives can be compared on the basis of a single figure for each alternative. This single figure represents the amount of money in today's dollars needed to cover all the expenditures associated with an alternative. Present worth costs are calculated using a 5 percent discount rate and a 30-year estimated project life. The present worth cost for Alternative 1 is $1,191,500,000. Capital costs and long-term operations and maintenance (O&M) costs are included in the total present worth cost. Long-term O&M costs are those associated with maintaining an alternative after implementation is complete.

ALTERNATIVE 2: EXCEEDS THE REQUIREMENTS OF ARARs

Alternative 2 is the most comprehensive of the alternatives that retain the current pond treatment system. It is the second of the two alternatives that exceed the requirements of a significant ARAR by providing full PMF protection to the pond system. Additional components include protecting the pond system against the maximum credible earthquake (MCE); excavation and offsite disposal of all tailings deposits and contaminated soils above the assumed action levels from areas above Pond 3 and below Pond 1; capping Pond 1; flooding tailings deposits and contaminated soils within Pond 2; and upgrading the treatment system in Pond 3. It also includes three of the components of Alternative 1: excavation of all tailings deposits and contaminated soils along the bypass, construction of an upstream flood impoundment, and installation of groundwater interception trenches. Disposal of excavated bypass material would occur offsite under this alternative.

Following the analysis of the first two criteria, the analysis of the alternative components that are the same as for Alternative 1 are not repeated. For the analysis of those components refer to the analysis of Alternative 1.

Overall Protection of Human Health and the Environment

Alternative 2 addresses all of the identified risks to human health and the environment present within the operable unit by using measures designed to maximize the control of the risks without eliminating the current pond treatment system.

Pond stability is addressed by protecting all three ponds against both a full MCE and a full PMF. Thus, the pond bottom sediments would be protected against the most extreme expectable conditions. While some damage to the pond berms may still occur under these extreme conditions, there would be minimal risk of losing the pond bottom sediments during an earthquake or flood event. Protection of the pond berms would continue for as long as the berms are properly maintained and repaired.

Alternative 2 would improve surface water quality for all flows by removing tailings from along the bypass and completely upgrading the pond treatment system. All surface water flows up to the theoretical maximum 100-year flood flow rate (4,000 cfs) would be treated in Pond 3, which would be upgraded to provide more effective and more consistent treatment. Pond 2 would be removed from the treatment system, eliminating the problem of resuspension of sediments during high winds and high flow rates. With the upgraded treatment system, most surface water quality

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exceedances should be avoided if the system is designed, built, and operated appropriately. The potential life of the pond has been estimated at approximately 70 to 80 years, long enough to complete remediation on the upper portions of the Silver Bow Creek site.

During flood flows between 600 and 4,000 cfs on Silver Bow Creek, the surface water would be detained in an upstream flood impoundment and released for later treatment in Pond 3. The flood impoundment would have adequate capacity to contain up to the volume of a 100-year flood. During floods exceeding the design capacity of the impoundment, 4,000 cfs or 8,000 acre-feet, a portion of the flow would be routed around the impoundment to protect the impoundment from damage due to overfilling. The majority (approximately 80 percent) of suspended solids would settle out in the impoundment. The flow equalization capacity provided by the impoundment would allow treatment of dissolved metals for all flood flows up to a 100-year event. The flood impoundment would significantly reduce the potential for the recontamination of the bypass by settled tailings, and the continued transport of tailings into the Clark Fork Basin during most flows.

Alternative 2 calls for contaminated groundwater to be collected both in and below Pond 1. The groundwater would then be pumped to the Pond 3 inlet for treatment in the pond system. This would reduce the discharge of metals loading into the Clark Fork River and should enable compliance with primary MCLs for groundwater at the downgradient edge of the most downgradient waste management unit.

Excavating the contaminated soils and tailings deposits wherever possible and disposing them in an offsite RCRA

treatment, storage, and disposal facility (TSDF) would permanently remove their associated hazards from the site, effectively isolate the tailings and soils from direct contact, and limit their mobility. However, offsite disposal of untreated material introduces a number of inherent risks, including transportation and disposal liability. Offsite disposal would not reduce the toxicity, volume, or persistence of the material itself.

All of the components of Alternative 2 are technically feasible. They would also, with the appropriate design, maintenance, and operation, reliably reduce the risks for which they are proposed. Increased risk to the surrounding environment and community during construction could be minimized by appropriate construction safety standards.

Compliance with ARARs

Within the conditional boundaries defined below, Alternative 2 should result in compliance with all the state and federal ARARs identified for the operable unit.

Stabilizing the pond berms against a full PMF would exceed the requirements of the Montana ARARs for protecting the pond system against flooding. Constructing an 8,000 acre-foot flood control impoundment and the comprehensive upgrade of the pond treatment system should result in effluent compliance with ambient and point source discharge surface water quality standards at flows up to a 100-year flood event and with Montana requirements for floodplain management. Excavating and moving tailings deposits and contaminated soils from the Mill-Willow Bypass, above Pond 3, and below Pond 1 to an offsite disposal facility and capping

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Pond 1 (with its waste in place) would comply with state and federal siting criteria for solid and hazardous waste disposal and would satisfy pertinent RCRA requirements for closure of a hazardous waste management facility. Pumping and treating groundwater would result in compliance with Montana groundwater standards. Table 8-4 presents a complete summary of this alternative's compliance with all ARARs identified by MDHES and USEPA.

The actions proposed in Alternative 2 could result in adverse effects on wetlands, endangered species, and historical resources. To mitigate these impacts, consultation with state and federal resource agencies will be required.

Long-Term Effectiveness

Alternative 2 addresses the identified risks at the site by using measures intended to limit or remove the risks. The primary risk at the site, the 19 million yards of sediments in the treatment ponds, would be addressed by raising, flattening, and armoring the existing berms around the ponds. This would protect the material in the ponds from the impacts of a maximum credible earthquake (MCE) or a probable maximum flood (PMF), reducing the likelihood of catastrophic pond failure and the release of pond sediments.

Residual risks at the site, after remediation, would result from the continued existence of the pond bottom sediments, the continued operation of Pond 3, and the development of the new flood impoundment. Because they would remain in an untreated form, the sediments could still migrate from the site in a dissolved or suspended form under some conditions. Sediments present in Pond 1 would be contained beneath a cap

designed to limit contact and infiltration. However, if the cap were not maintained, erosion could result in a release of the material beneath the cap.

The sediments and sludges in both Ponds 2 and 3 would be submerged but otherwise unmitigated. Releases of dissolved metals to the surface waters or the groundwater could occur as a result of changes in water chemistry, and resuspension of the metal sludges could occur as a result of high winds or high water flows in the system.

With the appropriate design, construction, operation, and maintenance, the modified Pond 3 treatment system proposed for Alternative 2 should be able to meet the appropriate water quality standards during all flows up to the theoretical maximum 100-year flood flow rate on Silver Bow Creek (4,000 cfs). The operation and maintenance tasks for Pond 3 would be the same as described for the new pond in Alternative 1. The projected pond life for Pond 3 under the proposed operating conditions is approximately 70 to 80 years. The entire Silver Bow Creek Site is projected to be remediated before that time. The pond treatment system would then no longer be needed.

Reduction of Toxicity, Mobility, Volume, Persistence, and Propensity to Bioaccumulate

The process proposed in Alternative 2 to stabilize the pond berms would address the primary threat at the site by providing improved containment of the 19 million cubic yards of sediments and sludges in the ponds. This would prevent a catastrophic release of the sediments and sludges and limit

the mobility of this material from the site except under extreme conditions. Capping Pond 1 would further reduce the possibility of release by isolating the material from the forces of weather.

The proposed processes to stabilize and isolate the sediments and tailings would not reduce the toxicity or volume of the material. Flooding the material in Pond 2 would reduce the possibility of wind release and inhalation, but would not substantially limit the mobility of the sludges near the surface. Dissolved releases from Pond 2 could still occur, though the potential for such releases would be greatly reduced by removing the pond from the treatment system and restricting the flow through the pond. Flooding currently dry areas in Pond 2 may also affect the quality of the groundwater beneath the pond. Groundwater trenches planned for Pond 1 would intercept this groundwater and pump it to Pond 3 for treatment.

The improved surface water and groundwater treatment systems would reduce the toxicity of water leaving the operable unit. Groundwater collection would reduce the mobility of the contaminated groundwater.

Excavation and offsite disposal of the tailings from along the bypass, above Pond 3, and below Pond 1 would eliminate direct contact with the tailings. The mobility of the tailings (at their new location) would be reduced, but not their toxicity, volume, or persistence, because the tailings would be landfilled without treatment. The potential for future recontamination of the bypass area would be reduced by the upstream impoundment, which would remove the settleable fraction of suspended solids before they reach

the bypass. Some potential for recontamination of the bypass would still exist during flood flows in excess of 4,000 cfs or 13,000 acre-feet, but that potential is small because at such high flow rates little settling would be expected.

Short-Term Effectiveness

Protection of the ponds against a PMF and an MCE would take approximately two construction seasons. During that time the risks to the Warm Springs community and the environment posed by the ponds would diminish. The overall protectiveness possible with Alternative 2 would not be attained until the project had been completed. The potential for increased risk to either the community or the environment during the berm stabilization process is limited. Remediation contractors would be at risk from exposure to and inhalation of contaminants during foundation excavation and associated tasks. These risks would be controlled by using protective equipment as necessary.

The reconstruction of the treatment system in Pond 3 would take 1 to 2 years to complete. Because it is needed for treatment, the pond would be kept online during the process. This may result in temporary releases of dissolved metals and suspended solids, and periodic exceedances of water quality standards by the pond discharge. This would affect the surface water environment but would have no impact on the Warm Springs community. The releases from the pond would also be less significant than if the pond were removed from service during remediation, which would require routing the contaminated creek flows to the Clark Fork River without treatment.

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Excavation and offsite disposal of exposed tailing above the designated action level would take approximately 2 years. The material would be sent to a RCRA facility in Idaho via rail.

The environmental impacts to the ponds resulting from the upgrading of the pond treatment system would be minimal because neither Pond 2 nor Pond 3 would be substantially affected by the changes. Although Pond 2 would be removed from the treatment system, the current water level would be maintained to isolate the pond bottom sediments. A minimal flow would continue through the pond to prevent the buildup of salts. The low volume of effluent from Pond 2 would be released to the bypass.

Planning for all of the remedial activities would have to consider potential impacts to a pair of bald eagles that have previously nested within the operable unit. The pair is not presently nesting in the area, but they continue to be sited in the areas around the ponds and the bypass. If the pair returns to nesting in the area, remediation scheduling would have to be revised to minimize potential impacts. This follows for all of the remaining alternatives.

The upgrade of the treatment system proposed for Alternative 2 would greatly affect the bypass, because all surface water entering the site would be directed into Pond 3. The bypass would be dry under normal conditions from the Pond 3 inlet to the Pond 3 outlet. Only during flows above the capacity of the flood impoundment (4,000 cfs or 13,000 acre-feet) would that portion of the bypass receive water. This would eliminate the fishery along that portion of the bypass.

Capping Pond 1 would take approximately one year to complete. While it is not likely that this would pose any additional threat to either the community or environment, it would substantially alter the current environment of Pond 1. Instead of being partially wetland and partially grassland, Pond 1 would become an entirely vegetated area. This would eliminate more than 100 acres of wetland habitat.

The remediation schedule for Alternative 2 is shown in Figure 8-2.

Implementability, Reliability, and Constructibility

It is feasible in Alternative 2 to protect the existing pond berms against a PMF and an MCE. The current uncertainties involve the lack of knowledge regarding suitable foundation material under the berms, the inside slope angles of the berms, and the actual value of the maximum credible earthquake. A preliminary investigation of the base material beneath the surface soils indicates that the material would be suitable as a foundation, but this would have to be investigated further during the design phase.

Upgrading the treatment system in Pond 3 should also be relatively straightforward. One potential difficulty would involve constructing a stable berm down the middle of Pond 3 on the 10 to 15 feet of sediments. Special design or materials considerations may be necessary to achieve a stable berm. This will have to be investigated further during design.

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TASK DESCRIPTION	1st YEAR												2nd YEAR												3rd YEAR												4th YEAR												5th YEAR											
	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
Design Investigations																																																										
Remedial Design																																																											
Land Acquisition																																																											
Permitting for Materials Quarries																																																											
Advertising, Bidding, and Award																																																											
Raise Berms Along Mill-Willow Bypass (Full PMF)																																																											
Construct Embankment																																																											
Place Riprap																																																											
Flood Control Berm Along Eastern Hills																																																											
Construct Embankment																																																											
Place Riprap																																																											
Improve Seismic Stability of Existing Berms																																																											
Foundation Construction																																																											
Construct Embankment																																																											
Upgrade Pond 3 Treatment System																																																											
Channelize Silver Bow Creek																																																											
Install Lime Treatment Facility																																																											
Improve Inlet Structure																																																											
Berm Across Pond 3																																																											
Construct Flow Control Structures																																																											
Excavate Exposed Tailings with Disposal at RCRA Facility																																																											
Excavate Below Pond 1																																																											
Excavate Above Pond 3																																																											
Excavate Along Mill-Willow																																																											
Haul to RCRA Facility																																																											
Dry Closure of Pond 1																																																											
Drain Pond																																																											
Place Soil Cap in Pond 1																																																											
Seeding and Watering																																																											
Wet Closure of Pond 2																																																											
Construct Upstream Flood Impoundment																																																											
Relocate Power Lines																																																											
Construct Berms																																																											
Construct Diversion Dam																																																											
Flow Control Structures																																																											
Groundwater Collection at Pond 1 with Treatment in Pond 3																																																											
Construct Groundwater Drains																																																											
Install Pipeline to Pond 3																																																											
Install Pump Station																																																											

FIGURE 8-2
ESTIMATED PROJECT SCHEDULE
FOR ALTERNATIVE 2
WARM SPRINGS PONDS OU 5

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All of the equipment needed in Alternative 2 to upgrade the pond treatment system should be readily available. The other equipment and supplies are either available or would be fabricated specifically for the site. Riprap for the berm would either be obtained locally or quarried specifically for the remedial effort. The lime needed to operate the treatment system is available from within Montana.

Disposing of the contaminated soils and tailings excavated from the bypass area, below Pond 1, and Pond 3 at an offsite facility would be difficult and costly. Approximately 160,000 cubic yards of material would have to be transported and disposed of. The nearest offsite treatment, storage, and disposal facility (TSDF) able to accept the waste from a federal Superfund site is Envirosafe Services, Inc., near Boise, Idaho. This is approximately 480 miles from the site, requiring a 960-mile round trip per load. The lowest cost transportation would be by rail. This would require construction of a siding for loading the cars and would take up to 2 years to complete.

Capping the material in Pond 1 with a RCRA-equivalent cap would be a feasible process for Alternative 2. Capping is a well-defined, extensively used process well suited for the material at the Warm Springs Ponds. The primary concern regarding the implementation of a RCRA-equivalent cap over Pond 1 would involve the local availability of suitable construction materials including agricultural lime (ag-lime) and clay. The cap would not include a flexible membrane liner. A preliminary survey indicates that the necessary materials should be available, but not necessarily locally.

Cost

Detailed cost estimates, including the assumptions used, are given in Appendix D. A summary of the capital costs associated with this alternative are shown in Table 8-8. Annual operation and maintenance costs are presented in Table 8-9. These costs are order-of-magnitude (+50 percent to -30 percent) estimates.

The present worth cost calculated for Alternative 2 is $241,500,000. Present worth was calculated using a 5 percent discount rate and a 30-year project life. Both capital costs and long-term operation and maintenance (O&M) costs are included in the total present worth cost.

ALTERNATIVE 3: COMPLIES WITH ARARs

Alternative 3 is similar to Alternative 2. The modifications between it and Alternative 2 increase its implementability but decrease its overall protectiveness. The components of Alternative 3 that are not a part of Alternatives 1 or 2 include protecting the pond system against fractions of a probable maximum flood (instead of a full PMF), construction of an upstream settling basin (instead of a flood impoundment), and excavation with onsite disposal of all contaminated soils and tailings above the assumed action levels from areas above Pond 3 and below Pond 1 (instead of offsite disposal). It also includes the following components from Alternatives 1 and 2:

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Table 8-8
WARM SPRINGS PONDS FEASIBILITY STUDY
COST EVALUATION OF ALTERNATIVES
ALTERNATIVE 2

Work Item Description		Cost Extensions Including Excess Labor Costs Due to Waste
MSA-1A:	Stabilize Pond Berms to Withstand A Probable Maximum Flood	$ 48,087,000
MSA-3:	Stabilize Berms to Withstand a Maximum Credible Earthquake	11,525,000
MSA-4:	Remove and Dispose of Contaminated Surface Soils Along Mill-Willow Bypass	45,116,000
MSA-5A:	Overall Upgrade of Pond 3 Treatment System	17,753,500
MSA-6A:	Construct an Upstream Flood Impoundment	19,399,000
MSA-9:	Excavate Exposed Tailings and Contaminated Soils from All Applicable Areas; Disposal at an Offsite RCRA Facility	39,075,000
MSA-12:	Groundwater Collection In and Below Pond 1 With Treatment in Pond 3	9,893,500
Subtotal Alternative 2		**190,849,000**
o Hazardous Waste Protection Costs		2,040,000
		192,889,000
o Division 1 Costs @ 11% of Total[a]		23,840,000
		216,729,000
o 15% Contingency		32,509,000
ESTIMATED CONSTRUCTION COST		**$249,238,000**
	Engineering Design	4,000,000
	Services During Construction	4,000,000
	Administrative and Legal	3,000,000
TOTAL PROJECT COST		**$261,000,000**

[a]Division 1 costs include allowances for general conditions, mobilization, permits, bond, insurance, and winter protection costs.

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Table 8-9
ANNUAL OPERATION AND MAINTENANCE COSTS
FOR ALTERNATIVE 2

Description	Annual Cost
Labor and Materials	$100,000
Chemicals and Power	125,000
Sampling and Testing	15,000
Equipment Replacement Reserve	51,000
Site Review	10,000
TOTAL	$301,000

- Upgrading the treatment system in Pond 3 (Alternative 2)
- Installation of groundwater interception trenches with treatment in Pond 3 (Alternative 2)
- Excavation of all tailings deposits and contaminated soils from along the bypass (Alternative 1)
- Capping Pond 1 and flooding Pond 2 (Alternative 2)

The analysis of the alternative components that are also parts of Alternative 1 and/or 2 are not repeated. For an analysis of those components refer to the alternative in which they first appear. Table 8-2 provides a summary of Alternative 3.

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Overall Protection of Human Health and the Environment

Alternative 3 addresses the identified risks to human health and the environment at the site with measures designed to control or eliminate the risks.

Pond stability is addressed by protecting the ponds against both the MCE and fractions of the PMF. The least protected of the ponds, Pond 1, would be protected against the flow of a 0.2 PMF, approximately six times the value of the theoretical maximum 100-year flood flow (29,000 cfs versus 4,900 cfs). Pond 2 would be protected against a 0.3 PMF. Pond 3 would be protected against a 0.5 PMF. Only under extreme flooding conditions would the stability of the pond berms be in question. Protection of the pond berms would continue for as long as the berms are properly maintained and repaired.

Alternative 3 would improve surface water quality for all flows up to 100-year flood flows of 4,000 cfs or 13,000 acre-feet by removing tailings from along the bypass, completely upgrading the existing pond treatment system, and constructing an upstream settling basin. All surface water flows up to 600 cfs would be treated in Pond 3, which would be upgraded to provide more effective and more consistent treatment. Up to 2,000 acre-feet of flows in excess of 600 cfs would also be treated in Pond 3. Pond 2 would be removed from the treatment system, eliminating the problem of resuspension of sediments during high winds and flow rates. With the upgraded treatment system, most of the surface water quality violations should be avoidable. The future life of Pond 3 has been estimated to be between 70 and 80 years.

During flood flows between 600 and 4,000 cfs, all surface water from Silver Bow Creek would pass through an upstream settling basin designed to remove suspended solids from the flow. Floods that do not completely fill the 2,000-acre-foot settling basin would be released slowly from the basin for treatment in Pond 3 at flows less than 600 cfs maximum. Floods in excess of 2,000 acre-feet would be only partially treated in Pond 3 (up to 600 cfs). The remainder of the flows discharged over the spillway of the settling basin would be routed around Pond 3 and flow down the bypass without treatment for dissolved metals. All flood flows up to 4,000 cfs would be routed through the settling basin, which would result in removal of up to 80 percent (weight basis) of the suspended particles. Thus, Alternative 3 would substantially reduce the potential for future recontamination of the bypass by settled tailings and reduce the continued transport of tailings into the Clark Fork Basin.

Contaminated groundwater moving from the site would be collected in and below Pond 1. It would then be pumped to the Pond 3 inlet for treatment in the pond system. This would reduce the discharge of metals loading into the Clark Fork River and should enable compliance with primary MCLs for groundwater at the selected compliance point.

Excavating the tailings deposits and contaminated soils and disposing of them under a RCRA-type cap in Pond 1 would effectively isolate them from direct contact and limit their mobility. The cap would provide a barrier from ingestion, inhalation, and runoff. As long as the cap is maintained, the material would be safe from releases due to erosion of the cap. Capping the material in Pond 1 would not, however, reduce the toxicity, volume, or persistence of the material.

All of the components of Alternative 3 are technically feasible. They would also, with the appropriate design, construction, operation, and maintenance, reliably reduce the risks for which they are proposed. Any increased risks to the surrounding environment and community during implementation can be kept to a minimum with appropriate containment and construction safety measures.

Compliance with ARARs

Within the site condition boundaries defined below, Alternative 3 should result in compliance with all the state and federal ARARs identified for the Warm Springs Ponds Operable Unit. Dam safety regulations and surface water quality standards would be satisfied up to lower flow rates in this alternative than in Alternatives 1 and 2.

The actions proposed for Alternative 3 meet the Montana ARARs for protecting the pond system against a fraction of a PMF and the full MCE. Construction of a 2,000 acre-foot settling basin and the comprehensive upgrade of the pond treatment system should result in effluent compliance with ambient and point source discharge surface water quality standards for all flows up to 600 cfs (the maximum capacity for the treatment system). Up to 2,000 acre-feet of flows between 600 cfs and 4,000 cfs on Silver Bow Creek would be retained for treatment. Remaining flows would only be treated by the settling basin for suspended solids. Once the settleable fraction of the suspended solids is removed, the water may meet the water quality standards without further treatment in Pond 3. If not, then the treatment provided by this alternative would fail the standards at

flows above 600 cfs. Silver Bow Creek can be expected to exceed 600 cfs approximately once every 2 years.

Alternative 3 should comply with Montana groundwater standards, and would satisfy Montana requirements for floodplain management. Excavating and moving tailings deposits and contaminated soils from the Mill-Willow bypass to Pond 1 prior to capping Pond 1 would comply with state and federal siting criteria for solid and hazardous waste disposal and could be done so as to satisfy pertinent RCRA requirements for closure of a hazardous waste management facility. Capping or revegetating the contaminated soils in-place could be designed and implemented to meet mining reclamation ARARs. A complete summary of this alternative's compliance with the state and federal ARARs is presented in Table 8-4.

The actions proposed in Alternative 3 could result in adverse effects on wetlands, endangered species, and historical resources. To mitigate these potential impacts, additional consultation with state and federal resource agencies will be required if this cleanup alternative is selected.

Long-Term Effectiveness

Alternative 3 addresses all of the identified risks at the site by using measures intended to limit or remove the risks. The primary risk at the site, the release of 19 million cubic yards of metal-contaminated tailings located in the treatment ponds, would be addressed by protecting the pond berms against failure due to a full MCE and fractions of a PMF. This would address the threat of pond failure in all but extreme cases.

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The lowest level of pond berm protectiveness in Alternative 3 would be 20 percent of a PMF for Pond 1. The predicted flow rate at 0.2 PMF is 29,000 cfs, approximately six times the predicted maximum flow rate of a 100-year flood in the same reach (4,900 cfs). Consequently, the threat of pond berm failures due to flooding, given the protectiveness of this alternative, would be small.

Residual risks would result from the continued existence of the 19 million cubic yards of sediments and sludge in the pond system although those risks would be reduced to a low level. In Alternative 3, the sediments in the ponds may still be released to the environment in either dissolved or suspended form under extreme conditions. This includes not only the sludges presently in the ponds, but also all the excavated soils and tailings from around the site that would be placed in Pond 1 prior to capping it.

Because the material beneath the cap would be untreated, maintenance and periodic inspection of the Pond 1 cap would be necessary. Maintenance activities would be directed at preventing erosion or deterioration of the cap. Periodic inspection and maintenance of the stabilized pond berms would also be necessary to ensure continued protection.

For this feasibility study, the upstream settling basin would be sized to capture tailings carried down Silver Bow Creek during flows above the capacity of the pond treatment system (600 cfs) to an upper limit flow of 4,000 cfs. This basin would settle up to 80 percent of the suspended solids flowing down the creek. Sedimentation of the remaining 20 percent of the loadings could lead to recontamination of the bypass. This is unlikely, however, because the basin

would settle out the coarser particles, allowing only the finer particles to reach the bypass. The very fine materials that would not settle in the basin are unlikely to settle along the bypass channel at flood flow rates.

Alternative 3 would be able to capture only 2,000 acre-feet of flood water for later treatment. Flood flows above the 2,000-acre-feet stored would continue to bypass the pond treatment system without treatment for dissolved metals.

The operation and maintenance requirements of the settling basin would primarily be upkeep of the mechanical parts of the system and the removal of settled solids following use. The settled solids would be collected for onsite disposal in one of the operating ponds (Ponds 2 or 3). Long-term, low-level contamination of the basin floor should be expected.

Reduction of Toxicity, Mobility, Volume, Persistence, and Propensity to Bioaccumulate

Protecting the pond berms against failure due to a full MCE and fractions of a PMF would substantially reduce the potential mobility of the sludges in the ponds, although this would not affect their volume, persistence, or toxicity. Only in the extreme case of flooding above the design floods for Alternative 3 would the current containment of the pond bottom sediments be affected.

Onsite disposal of excavated soils and tailings beneath a RCRA-equivalent cap in Pond 1 would reduce the mobility of those materials. The materials would be taken from currently exposed areas along the bypass, and above and below the pond system. The RCRA-equivalent cap on Pond 1

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would prevent direct contact with the material. The pond bottom sediments in Ponds 2 and 3 would remain covered by water but would not be completely immobilized against wind and water action.

The toxicity, volume, persistence, and propensity to bioaccumulate of the pond bottom sediments and the tailings deposits and contaminated soils would not be altered by the proposed actions of Alternative 3.

The upstream settling basin would address the principal threat resulting from flood flows above 600 cfs, the transport of tailings through the system and into the Clark Fork basin, by ensuring that all flows through the reach, up to the theoretical maximum 100-year flood flow of 4,000 cfs, are at least treated for suspended solids. (Above 4,000 cfs, a fuse plug would wash out and all subsequent flows would continue down Silver Bow Creek without passing through the settling basin.) Flows of less than 600 cfs and 2,000 acre-feet of flows above 600 cfs would continue to be treated in the pond system for dissolved and suspended solids. The settling basin proposed for Alternative 3 would remove up to 80 percent of the suspended solids in flows between 600 and 4,000 cfs. The solid residuals of the settling could be removed to Pond 2 or 3 at a later date. The toxicity and volume of the solids would remain unchanged even with disposal.

Flows in excess of 4,000 cfs would bypass the settling basin through the fuse plug. They would not be treated in either the settling basin or Pond 3. This may lead to short-term water quality exceedances in the effluent from the operable unit during high flows, but it would probably not have a long-term impact on the operable unit.

Short-Term Effectiveness

It would take approximately two construction seasons to protect the pond berms against an MCE and fractions of a PMF. During that time, the protectiveness provided for the downstream community of Warm Springs and the environment would increase. The overall level of protectiveness of Alternative 3 would not be attained until construction had been completed. The potential for increased risk to either the community or the environment during the berm stabilization process is limited. Remediation contractors would be at risk from direct contact and inhalation of contaminants during foundation excavation and associated tasks. These risks would be controlled by using protective equipment as necessary.

Because it would be built off-channel and upstream of the present pond system, the settling basin would not affect either the community of Warm Springs or the local environment during construction. Risks to the remediation contractors would be limited to standard construction risks associated with similar projects. The diversion and inlet structures would be constructed in the contaminated stream channel. Precautions would be required to avoid excessive additional contamination of the creek flows during construction of these features. The only identified long-term environmental impact would be the removal of approximately 500 acres of rangeland from use. Construction of the settling basin for Alternative 3 would take 1 to 2 years to complete.

The remediation schedule for Alternative 3 is shown in Figure 8-3.

Implementability, Reliability, and Constructibility

Protecting the pond berms against an MCE and fractions of a PMF would be feasible in Alternative 3. The current uncertainties involve the existence of suitable foundation material downstream of the toes of the existing berms, the nature of the upstream slopes, and the actual value of the maximum credible earthquake. Preliminary investigations indicate that the base material beneath the surface soils would be adequate, but this will have to be verified during the design phase. The materials and construction of the upstream slopes, and the maximum credible earthquake also will have to be determined during the design phase.

The availability of suitable riprap and fill material for the stabilization process may affect the implementation of Alternative 3. At this time, no suitable local source of riprap has been identified. But, if necessary, a quarry could be opened to obtain the material specifically for this task. Land acquisition would be required for the upstream settling basin.

Cost

Detailed cost estimates, including the assumptions used, are given in Appendix D. A summary of the capital costs associated with this alternative are shown in Table 8-10. Annual operation and maintenance costs are presented in Table 8-11. These costs are order-of-magnitude (+50 percent to -30 percent) estimates.

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TASK DESCRIPTION	1st YEAR	2nd YEAR	3rd YEAR	4th YEAR	5th YEAR
	J F M A M J J A S O N D	J F M A M J J A S O N D	J F M A M J J A S O N D	J F M A M J J A S O N D	J F M A M J J A S O N D
Design Investigations					
Remedial Design					
Land Acquisition					
Permitting for Materials Quarries					
Advertising, Bidding, and Award					
Raise Berms Along Mill-Willow Bypass (Part. PMF)					
Construct Embankment					
Place Riprap					
Improve Seismic Stability of Exisiting Berms					
Foundation Construction					
Construct Embankment					
Upgrade Pond 3 Treatment System					
Channelize Silver Bow Creek					
Install Lime Treatment Facility					
Improve Inlet Structure					
Berm Across Pond 3					
Construct Flow Control Structures					
Construct Upstream Settling Basin					
Relocate Power Lines					
Construct Berms					
Construct Diversion Dam					
Construct Flow Control Structures					
Remediation of Contaminated Soils and Tailings					
Excavate Below Pond 1					
Excavate Above Pond 3					
Excavate Along Mill-Willow Bypass					
Drain Pond 1					
Place Cap on Pond 1					
Seeding and Watering					
Wet Closure of Pond 2					
Groundwater Collection at Pond 1 with Treatment In Pond 3					
Construct Groundwater Drains					
Install Pipeline to Pond 3					
Install Pump Station					

FIGURE 8-3

ESTIMATED PROJECT SCHEDULE
FOR ALTERNATIVE 3
WARM SPRINGS PONDS OUFS

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Table 8-10
WARM SPRINGS PONDS FEASIBILITY STUDY
COST EVALUATION OF ALTERNATIVES
ALTERNATIVE 3

Work Item Description		Cost Extensions Including Excess Labor Costs Due to Waste
MSA-1B:	Stabilize Pond Berms to Withstand Flood Flows Less Than the Probable Maximum Flood	$ 7,494,500
MSA-3:	Stabilize Berms to Withstand a Maximum Credible Earthquake	3,000,000
MSA-4:	Remove and Dispose of Contaminated Surface Soils Along Mill-Willow Bypass	1,191,000
MSA-5A:	Overall Upgrade of Pond 3 Treatment System	5,816,000
MSA-6B	Construct an Upstream Settling Basin	10,721,000
MSA-10:	Excavate Exposed Tailings and Contaminated Soils from All Applicable Areas; Disposal at an Onsite Non-RCRA Facility (Pond 1)	14,579,000
MSA-12:	Groundwater Collection In and Below Pond 1 With Treatment in Pond 3	1,930,500
Subtotal Alternative 3		**44,732,000**
o	Hazardous Waste Protection Costs	1,760,000
		46,492,000
o	Division 1 Costs @ 11% of Total[a]	5,746,000
		52,238,000
o	15% Contingency	7,836,000
ESTIMATED CONSTRUCTION COST		**$60,074,000**
	Engineering Design	4,200,000
	Services During Construction	4,200,000
	Administrative and Legal	3,000,000
TOTAL PROJECT COST		**$71,500,000**

[a]Division 1 costs include allowances for general conditions, mobilization, permits, bond, insurance, and winter protection costs.

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Table 8-11
ANNUAL OPERATION AND MAINTENANCE COSTS
FOR ALTERNATIVE 3

Description	Annual Cost
Labor and Materials	$ 94,000
Chemicals and Power	130,000
Sampling and Testing	15,000
Equipment Replacement Reserve	51,000
Site Review	10,000
TOTAL	$300,000

The present worth cost calculated for Alternative 3 is $71,100,000. Present worth was calculated using a 5 percent discount rate and a 30-year project life. Capital costs and long-term operations and maintenance (O&M) costs are included in the total present worth cost.

ALTERNATIVE 4: COMPLIES WITH ARARs

Alternative 4 contains many of the same components as Alternative 3 with one important difference. Tailings and contaminated soil in the areas above Pond 3 and below Pond 1 and above the action levels of 250 ppm arsenic and 750 ppm lead would be capped in-place rather than excavated and disposed of onsite.

The other components of Alternative 4 are also part of one or more of the first three alternatives. The components are analyzed against the five primary evaluation criteria as part of the evaluation of the alternative in which they first appear. These components include:

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- Protecting the pond system against fractions of a PMF and a full MCE (Alternative 3)

- Excavation with onsite disposal of all tailings and contaminated soils from along the bypass (Alternative 1)

- Upgrading the treatment system in Pond 3 (Alternative 2)

- Construction of an upstream settling basin for flood flows (Alternative 3)

- Installation of groundwater interception trenches with treatment in Pond 3 (Alternative 2)

- Capping Pond 1 and flooding Pond 2 (Alternative 2)

Overall Protection of Human Health and the Environment

Alternative 4 addresses the identified risks to human health and the environment present at the site with measures designed to control or remove the risks.

Pond stability is addressed in Alternative 4 by protecting the ponds against both the MCE and a fraction of the PMF. The least protected of the ponds, Pond 1, would be protected against the flow of a 0.2 PMF, approximately six times the flow of a 100-year flood. Only under extreme flooding conditions would the stability of the pond berms be in question.

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Alternative 4 would improve surface water quality for the majority of flows by removing tailings from along the bypass and upgrading the pond treatment system. Surface water flows of up to 600 cfs into the operable unit would be treated in Pond 3, which would be upgraded to provide more effective and consistent treatment. Pond 2 would be removed from the treatment system; Pond 3 discharge would flow directly into the bypass. With the upgraded treatment system most surface water quality exceedances should be avoidable.

Surface water quality would also be improved during flood flows between 600 and 4,000 cfs through the addition of an upstream settling basin designed to settle out approximately 80 percent of the suspended solids loading. This would reduce the potential for future recontamination of the bypass by settled tailings and the continued transport of tailings into the Clark Fork Basin. The settling basin would provide storage for 2,000 acre-feet of water entering the settling basin. The remaining water would be discharged over the spillway of the settling basin, passing through the operable unit without treatment in Pond 3 for dissolved metals.

Contaminated groundwater moving from the site would be collected in and below Pond 1. It would then be pumped to the Pond 3 inlet for treatment. This would reduce the discharge of metals loading into the Clark Fork River and result in compliance with primary MCLs at the compliance point.

Capping the contaminated soils and tailings deposits in-place wherever possible would effectively isolate them from direct contact and limit their mobility. For as long as the

cap is maintained, the capped areas within the pond berms would be safe from erosion. Adequate ground cover on top of contaminated soils would provide a barrier from ingestion, inhalation, and runoff. However, the area below Pond 1 (76 acres) could not reasonably be protected from erosion during major floods. The costs of protecting a cap in a floodplain area such as this would be very high. (It would be cheaper and more effective to move these materials to Pond 1 and cap them there where they would be protected from floods by the pond berms.) Flooding Pond 2 would reduce the risk of direct contact but would not reduce the material's mobility. Neither flooding nor capping the soils and tailings would reduce the toxicity, volume, or persistence of the material.

All of the components of Alternative 4 are technically feasible. With the appropriate design, construction, operation, and maintenance, they would also reliably reduce the risks for which they are proposed, except as noted for the capped area below Pond 1. Any increased risks to the surrounding environment and community during implementation would be minimized by containment and construction safety measures.

Compliance with ARARs

Within the conditional boundaries defined below, Alternative 4 should result in compliance with all the state and federal ARARs identified for this operable unit. However, dam safety regulations and surface water quality standards would not be satisfied over the same broad range of flow rates as under Alternatives 1 and 2.

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The actions proposed would meet the Montana ARARs for protecting the pond system against flooding and earthquakes. Construction of a 2,000-acre-foot settling basin and the comprehensive upgrade of the pond treatment system should result in effluent compliance with surface water quality standards at flows up to at least 600 cfs. It is expected that this 600-cfs flow would be exceeded once every 2 years. Up to 2,000 acre-feet of flows above 600 cfs would also be retained for treatment. Remaining flows above 600 cfs would be treated for suspended solids only. This water may meet the water quality standards without further treatment.

Alternative 4 would comply with Montana requirements for floodplain management. Excavating and moving tailings deposits and contaminated soils from the Mill-Willow bypass to Pond 1 prior to capping Pond 1 would comply with state and federal siting criteria for solid and hazardous waste disposal and could be done so as to satisfy pertinent RCRA requirements for closure of a hazardous waste management facility. A complete summary of alternative action compliance with the state and federal ARARs addressed in this chapter is presented in Table 8-4. Groundwater collection and treatment would result in compliance with Montana groundwater standards.

The actions proposed in Alternative 4 could result in adverse effects on wetlands, endangered species and historical resources. To mitigate these potential impacts, consultation with state and federal resource agencies will be required.

Long-Term Effectiveness

Alternative 4 addresses the identified risks at the site by using measures intended to limit or remove the risk. The new component, capping contaminated soil and tailings in place, was included to address one of these risks.

Capping the majority of the contaminated soils and tailings in place would avoid the risks associated with excavation and redisposal of that material. However, Alternative 4 would not address the residual risks associated with leaving 1.7 million cubic yards of soil and tailings untreated and spread throughout the site. This is particularly relevant in the area below Pond 1. Monitoring and maintenance requirements would be increased by keeping the material spread out because each area would have to be treated as a separate cap.

Reduction of Toxicity, Mobility, Volume, Persistence, and Propensity to Bioaccumulate

Capping the contaminated soils and tailings in place in the areas above and below the ponds would effectively reduce the mobility of the material except during cases of extreme flooding in the area below Pond 1. It would not affect the material's toxicity or volume. It would also isolate the material to inhibit human and environmental exposure. In Alternative 4, all of the soils and tailings identified as being above the action level would be contained under a cap or, as in the case of Pond 2, under a water surface.

Short-Term Effectiveness

The protectiveness against release of contaminated soils and tailings would increase as the capping project progressed. Capping all of the areas involved would take approximately 2 years. The primary risk to the remediation contractors would be from inhalation of dust and dermal contact with the tailings and soils. This would be controlled using appropriate personal protective equipment.

Capping the contaminated soils and tailings in place would temporarily affect the terrestrial wildlife habitat in the areas around the ponds. However, the isolation of the contaminated material would improve the quality of the habitat and the capping and revegetation program would return the area to terrestrial habitat use.

The remediation schedule for Alternative 4 is shown in Figure 8-4.

Implementability, Reliability, and Constructibility

No major difficulties are expected with capping the tailings and contaminated soils in place. The key concern would be the availability of materials for capping approximately 325 acres of land, the total acreage with material above the action level.

Cost

Detailed cost estimates, including the assumptions used, are given in Appendix D. Annual operation and maintenance costs are presented in Table 8-12. A summary of the capital costs

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TASK DESCRIPTION	1st YEAR												2nd YEAR												3rd YEAR												4th YEAR												5th YEAR											
	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
Design Investigations																																																									
Remediol Design																																																											
Land Acquisition																																																											
Permitting for Materials Quorries																																																											
Advertising, Bidding, and Award																																																											
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Construct Embonkment																																																											
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Construct Embonkment																																																											
Upgrade Pond 3 Treatment System																																																											
Channelize Silver Bow Creek																																																											
Install Lime Treatment Facility																																																											
Improve Inlet Structure																																																											
Berm Across Pond 3																																																											
Construct Control Structures																																																											
Construct Upstream Settling Basin																																																											
Relocate Power Lines																																																											
Construct Berms																																																											
Construct Diversion Dam																																																											
Construct Flow Control Structures																																																											
Remediation of Contaminoted Soils and Tailings																																																											
Excavate Below Pond 1																																																											
Excavate Along Mill-Willow Byposs																																																											
Drain Pond 1																																																											
Place Soil Cop on Ponds 1, 2, and 3																																																											
Seeding and Watering																																																											
Groundwater Collection at Pond 1 with Treatment in Pond 3																																																											
Construct Groundwater Drain																																																											
Install Pipeline to Pond 3																																																											
Install Pump Station																																																											

FIGURE 8-4

ESTIMATED PROJECT SCHEDULE
FOR ALTERNATIVE 4
WARM SPRINGS PONDS OUFS

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Table 8-12
ANNUAL OPERATION AND MAINTENANCE COSTS
FOR ALTERNATIVE 4

Description	Annual Cost
Labor and Materials	$ 96,000
Chemicals and Power	120,000
Sampling and Testing	22,000
Equipment Replacement Reserve	45,000
Site Review	10,000
TOTAL	$293,000

associated with this alternative are shown in Table 8-13. These costs are order-of-magnitude (+50 percent to -30 percent) estimates.

The present worth cost calculated for Alternative 4 is $77,000,000. Present worth was calculated using a 5 percent discount rate and a 30-year project life. Capital costs and long-term operations and maintenance (O&M) costs are included in the total present worth cost.

ALTERNATIVE 5: SIGNIFICANT PROTECTION OF HEALTH, WELFARE, AND ENVIRONMENT

Alternative 5 is the last of the comprehensive alternatives addressing each of the identified ARARs violations and human health concerns identified for the Warm Springs Ponds. It differs from the previous alternatives in that it proposes a partial modification to the treatment system in Pond 3, rather than the complete upgrade identified in Alternatives 2, 3, and 4, and a downstream wetland treatment system to treat contaminated groundwater.

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Table 8-13
WARM SPRINGS PONDS FEASIBILITY STUDY
COST EVALUATION OF ALTERNATIVES
ALTERNATIVE 4

Work Item Description		Cost Extensions Including Excess Labor Costs Due to Waste
MSA-1B:	Stabilize Pond Berms to Withstand Flood Flows Less Than the Probable Maximum Flood	$ 7,494,500
MSA-3:	Stabilize Berms to Withstand a Maximum Credible Earthquake	3,031,500
MSA-4:	Remove and Dispose of Contaminated Surface Soils Along Mill-Willow Bypass	1,027,000
MSA-5A:	Overall Upgrade of Pond 3 Treatment System	5,608,250
MSA-6B	Construct an Upstream Settling Basin	11,111,000
MSA-7:	Cap Below Pond 1, Within Ponds 1 and 2, and Above Pond 3	19,124,000
MSA-12:	Groundwater Collection and Piping to Pond 3 Inlet	1,898,800
Subtotal Alternative 4		**49,295,050**
o Hazardous Waste Protection Costs		1,340,000
		50,635,050
o Division 1 Costs @ 11% of Total[a]		6,257,950
		56,893,000
o 15% Contingency		8,534,000
ESTIMATED CONSTRUCTION COST		**$65,427,000**
	Engineering Design	4,600,000
	Services During Construction	4,600,000
	Administrative and Legal	3,300,000
TOTAL PROJECT COST		**$78,000,000**

[a]Division 1 costs include allowances for general conditions, mobilization, permits, bond, insurance, and winter protection costs.

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The partial upgrade of the pond treatment system would include only specific pieces of the comprehensive upgrade outlined for Alternatives 2 through 4:

- Diversion of Mill and Willow Creeks into Pond 3
- Modification of the Pond 3 inlet
- Improved lime treatment

The other components of Alternative 5 are also included in the first four alternatives. The components are evaluated against the five primary criteria as part of the evaluation of the alternative in which they first appear. These components include:

- Protecting the pond system against fractions of a PMF and a full MCE (Alternative 3)
- Excavation with onsite disposal of contaminated soils and tailings from the bypass (Alternative 3)
- Construction of an upstream settling basin (Alternative 3)
- In-place capping of all unvegetated material (soils and tailings) above the assumed action levels of 250 ppm arsenic and 750 ppm lead, and flooding such areas in Pond 2 (Alternative 4)

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Overall Protection of Human Health and the Environment

Alternative 5 addresses the identified risks to human health and the environment present at the site with measures designed to control or eliminate the risks. Pond stability is addressed by protecting the ponds against both the MCE and a fraction of the PMF. The least protected of the ponds, Pond 1, would be protected against the flow of a 0.2 PMF, approximately six times the flow of a 100-year flood. Pond 2 would be protected against a 0.3 PMF. Pond 3 would be protected against a 0.5 PMF. Only under extreme flooding conditions would the stability of the pond berms be in question.

Alternative 5 would improve surface water quality during for flows up to 210 cfs by removing tailings from along the bypass and upgrading the pond treatment system. Because of the limited capacity of Pond 2, flows into the pond system would be limited to under 210 cfs. This could result in the violation of water quality standards during some above-average flow events, but it will also prevent the resuspension and release of pond bottom sediments from Pond 2. The permanence of the system could be limited because the future life of Pond 2 has been estimated at less than 15 years. The effectiveness of the pond would continue to degrade until it has been removed from use.

Surface water quality would be improved during flows greater than 210 cfs through the addition of an upstream settling basin designed to settle out approximately 80 percent of the suspended solids loading. Up to 2,000 acre-feet of water would be detained in the settling pond basin and could slowly be entered into the pond system for treatment (at up

to 210 cfs total flow for Mill, Willow, and Silver Bow Creeks and the release from the basin). This would offset somewhat the lack of dissolved metals treatment for above average flows, and limit the recontamination of the bypass and the continued transport of tailings into the Clark Fork River.

Flows between 210 and 4,000 cfs that total more than 2,000 acre-feet would be treated in the settling basin for suspended solids only before being released to the bypass without treatment for dissolved metals. Flows above 4,000 cfs would pass through the operable unit without treatment for either suspended solids or dissolved metals.

Contaminated groundwater moving from the site would be collected below Pond 1 and treated in an onsite wetland treatment system. This would restrict the discharge of further metals loading into the Clark Fork River. The permanence of the wetlands system will depend on the level of maintenance undertaken on the system. Left alone, the system would likely operate effectively for up to 10 years. With proper maintenance, the wetland would have a life expectancy of 70 to 80 years. Alternative 5 does not include groundwater collection from within Pond 1.

Capping the tailings deposits and contaminated soils in most areas would isolate them from direct contact and hinder their mobility. It would not reduce the toxicity, volume, or persistence of the material.

All of the components of Alternative 5 are technically feasible. With the appropriate design, construction, operation, and maintenance, they would also reliably reduce the risks

for which they are proposed. Increased risks to the surrounding environment and community during construction would be minimized by appropriate containment and construction safety measures.

Compliance with ARARs

Under the conditions defined below, Alternative 5 would result in compliance with many of the state and federal ARARs identified for the Warm Springs Ponds Operable Unit. However, as described below, certain significant ARARs for the operable unit would not be met.

The actions proposed meet the Montana ARARs for protecting the pond system against flooding and earthquakes. However, construction of a 2,000 acre-foot settling basin, with only limited improvements to the pond treatment system, may result in regular violations of ambient and point source surface water quality standards for above average flows since flows in excess of 210 cfs would only be treated for suspended solids. Treating contaminated groundwater in an onsite wetland should result in compliance with Montana groundwater quality criteria. However, wetland treatment may not be as consistently reliable, especially during the winter, as the pond treatment system proposed in Alternatives 1 through 4. Excavating and moving tailings deposits and contaminated soils from the Mill-Willow bypass to Pond 1 prior to capping Pond 1 would comply with state and federal siting criteria for solid and hazardous waste disposal and could be carried out so as to satisfy pertinent RCRA requirements for closure of hazardous waste management facilities. A complete summary of alternative action compliance with the state and federal ARARs addressed in this chapter is presented in Table 8-4.

The actions proposed in Alternative 5 could result in adverse affects on wetlands, endangered species and historical resources. To mitigate these potential impacts, additional consultation with state and federal resource agencies will be required if this cleanup alternative is selected.

Long-Term Effectiveness

Alternative 5 addresses the identified risks at the site with measures intended to limit or remove the risk. The two new components in Alternative 5--a less comprehensive upgrade of the treatment system in Ponds 2 and 3 and wetlands treatment of collected groundwater--address specific risks to human health and the environment. The remainder of the components have been discussed as part of one of the first four alternatives.

The tasks identified for Alternative 5 as part of the partial upgrade of the treatment system include only those items necessary to meet the appropriate ambient and point source discharge standards for surface water under normal operating conditions. This includes an improved inlet structure to direct all flows up to 210 cfs into the pond and an improved lime treatment system to consistently maintain an adequate pH for treatment in the ponds. It also includes a provision to direct flows from Mill and Willow Creeks into the ponds for treatment, as long as the combined flows of the three creeks remain under 210 cfs. Alternative 5 does not, however, reduce potential short-circuiting within Pond 3 or remove Pond 2 from the treatment system. Short-circuiting decreases the effectiveness of the treatment by decreasing the residence time in the pond.

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Keeping Pond 2 in the treatment system presents a much greater residual risk. Because it is nearly full of sludge and sediment (average water depth is 2 to 3 feet), sediments are currently reentrained during periods of higher flows and/or high winds. Pond 2 appears to remove metals only at flows of less than approximately 210 cfs. Accordingly, the components of the pond system upgrade would limit flows into the ponds to below that number. Resuspension of the sediments may still result during periods of high winds.

The operation and maintenance requirements for the treatment system in Alternative 5 would be limited to cleaning the trashrack as necessary and maintaining operation of the lime treatment system. During the winter months, lime would have to be brought to the site and fed to the liming units every couple of days. Within the next 10 to 20 years, Pond 2 would eventually have to be taken offline, since it would continue to accumulate sludge and sediment for as long as it remains in use.

Periodic monitoring would be required to assess the treatment system's effluent and its effect on local groundwater.

The wetlands treatment system would be used to treat groundwater collected in trench drains from below Pond 1 prior to discharging the water to the Clark Fork River. Trench drains are only planned for the area below Pond 1 as part of this alternative. Groundwater exiting from the pond system would be captured in the trench and conveyed to the wetland. Wetlands treatment for metals removal is an innovative technology and its long-term effectiveness for treating the contaminated groundwater is unknown. Wetlands systems have

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been used with varying degrees of success in treating acid mine drainage containing metal contamination, including concentrations much higher than detected in the groundwater at Warm Springs Ponds. Based on the results obtained elsewhere, it is expected that a wetlands treatment system would be capable of meeting the appropriate standards for the contaminated groundwater at this site.

There are a number of difficulties inherent to the wetlands treatment system. The primary concern is that the system would not be capable of meeting the designated water quality standards over the long term without a substantial startup effort to acclimate the plant species and establish a renewable biomass. This cannot be fully known until the system is in place and operating, although wetland pilot studies would be helpful in determining the overall effectiveness of the system. A second problem is that through the uptake of the toxic metals, the whole biomass of the wetlands will periodically have to be removed for disposal. Because of metals loadings, the biomass may not be suitable for animal forage. Precipitation of metals and the sedimentation of biomass in the wetland could lead to increased contamination of the soil and, potentially, the groundwater in that area. Ice formation and buildup in the winter can also lead to severe short-circuiting and a significant reduction in treatment. Finally, because the wetland would be located in an unprotected area below Pond 1, the potential exists for substantial damage to the wetlands during a flood.

Because the wetlands system does not include the installation of a trench drain in Pond 1, increased quantities of contaminated groundwater would continue to migrate from its

source (Pond 2). However, this groundwater would be captured in the trench below Pond 1 prior to migrating from the site. The net effect is likely to be an increase in the difficulty of dewatering and capping Pond 1.

Operation, maintenance, and monitoring of the wetlands system would be extensive during the first few years. Once the system was established and groundwater standards were being routinely met, all three tasks would decrease though continue.

Reduction of Toxicity, Mobility, Volume, Persistence, and Propensity to Bioaccumulate

Modifying the pond treatment system would reduce the toxicity of the water flowing down Mill, Willow, and Silver Bow Creeks by reducing levels of metal contaminants and suspended solids loads in the creek water. The system proposed for Alternative 5 would provide pond treatment for flows up to 210 cfs. Flows above 210 cfs in excess of 2,000 acre-feet would be treated for suspended solids only. The metals removed from the pond system would be settled out as a lime-based sludge. The sludge would have decreased mobility but increased volume. It could also resuspend under the right conditions (e.g., high winds in Pond 2).

The wetlands system of Alternative 5 is designed to reduce the metals loadings in the groundwater below Pond 1. Once operating to specifications, the wetland system is expected to act as a passive treatment system, much like the ponds themselves. The system should be able to treat all of the groundwater to meet the primary MCLs. A substantial portion of the metals removed from the water would be transferred to

the wetland biomass, both plants and algae, where they would accumulate until the biomass is removed through death or harvesting.

Biological uptake of the material would decrease the mobility and toxicity of contaminants in the groundwater. The volume of the remaining toxic material in the effluent would be substantially reduced. However, the treatment residuals from this process may require special disposal because of the increased metals levels in the soils and biota. The potential for surface water discharge of the contaminants would also increase through the operation of a wetlands treatment system. Periodic cleaning or dredging and partial replacement of the plant life in the wetland may also be necessary in Alternative 5 to remove sediments with high loadings that have accumulated. Leaching of metals from the sediments may result in an increased groundwater problem in this area, although the magnitude or impact of such a problem cannot be defined at this time.

Short-Term Effectiveness

Neither of the new components of Alternative 5 should result in substantial short-term risks to the Warm Springs community or the environment during remediation.

An improvement in water quality in the Clark Fork River would not be realized until after the upgrading project had been completed. This would take approximately 1 year.

Alternative 5 calls for the wetlands treatment system to be constructed below Pond 1 in an area of tailings deposits and contaminated soils. These materials would be removed prior

to construction of the wetlands as part of the soils remediation component of this alternative. The risks to the Warm Springs community and the surrounding environment during the actual construction and development of the wetlands are expected to be minimal. Environmentally, development of a wetlands system would have a positive impact on the operable unit because it would replace the current wetland area established in tailings deposits and contaminated soils with a new, more stable area. Once the tailings and contaminated soil were removed, risks to the remediation contractors would be limited to standard construction risks associated with similar projects. Constructing a wetland treatment area would take approximately 1 year; developing and optimizing the system could take up to 5 years.

In Alternative 5, the environmental impacts to the current ponds resulting from a modification of the pond treatment system would be minimal since no part of the current configuration would be affected. Modifying the pond system would greatly affect a portion of the bypass, however, since all surface water entering the site up to 210 cfs would be directed into the ponds. The bypass would therefore be dry under normal conditions from the Pond 3 inlet to the Pond 2 outlet. Only during flows in excess of 210 cfs and 2,000 acre-feet would this reach of the bypass receive water. This would eliminate the fishery along that portion of the bypass.

The remediation schedule for Alternative 5 is shown in Figure 8-5.

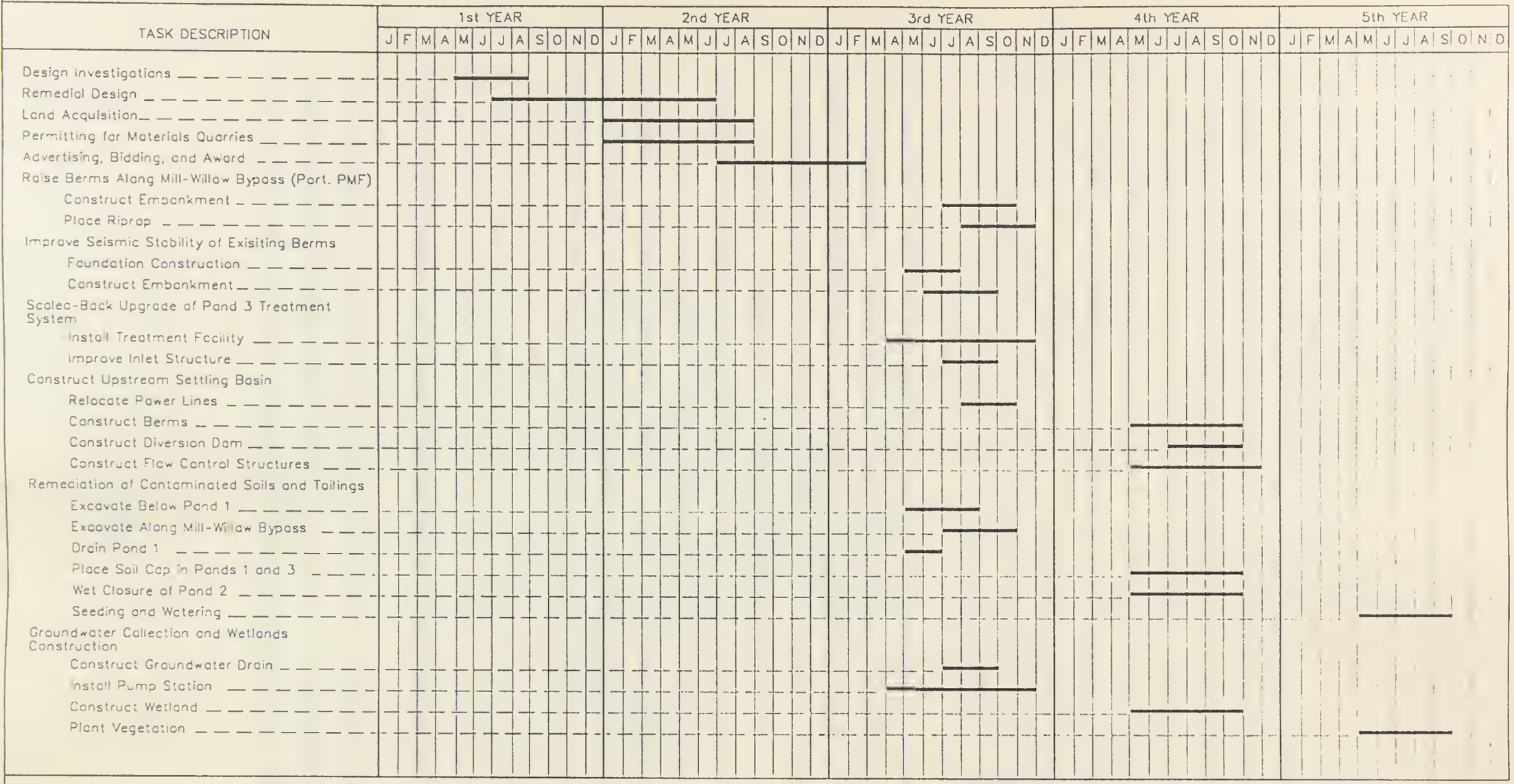

FIGURE 8-5

ESTIMATED PROJECT SCHEDULE
FOR ALTERNATIVE 5
WARM SPRINGS PONDS OU#5

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Implementability, Reliability, and Constructibility

Major difficulties are not expected with the construction or implementation of either the modification of the treatment system or the wetlands treatment system. But, effective operation of the wetlands treatment system may prove difficult. Because it is an innovative technology with limited background information, the reliability of the process for long-term treatment cannot be fully assessed. Similar systems treating acid mine drainage have had varying degrees of success. A long optimization and implementation process may be required in order to get the system to operate effectively.

Cost

Detailed cost estimates, including the assumptions used, are given in Appendix D. A summary of the capital costs associated with this alternative are shown in Table 8-14. Annual operation and maintenance costs are presented in Table 8-15. These costs are order-of-magnitude (+50 percent to -30 percent) estimates.

The present worth cost calculated for Alternative 5 is $66,300,000. Present worth was calculated using a 5 percent discount rate and a 30-year project life. Capital costs and long-term operations and maintenance (O&M) costs are included in the total present worth cost.

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Table 8-14
WARM SPRINGS PONDS FEASIBILITY STUDY
COST EVALUATION OF ALTERNATIVES
ALTERNATIVE 5

Work Item Description		Cost Extensions Including Excess Labor Costs Due to Waste
MSA-1B:	Stabilize Pond Berms to Withstand Flood Flows Less Than the Probable Maximum Flood	$ 7,494,500
MSA-3:	Stabilize Berms to Withstand a Maximum Credible Earthquake	3,031,500
MSA-4:	Remove and Dispose of Contaminated Surface Soils Along Mill-Willow Bypass	917,000
MSA-5B	Less comprehensive upgrade of the Pond Treatment System	1,484,750
MSA-6B	Construct an Upstream Settling Basin	11,047,000
MSA-7:	Capping and Revegetating Contaminated Soils and Exposed Tailings in Ponds 1 and 3. Excavate Below Pond 1 and Flood Pond 2.	13,662,000
MSA-11:	Groundwater Collection and Wetland Treatment Below Pond 1	3,948,300
Subtotal Alternative 5		**41,585,050**
o	Hazardous Waste Protection Costs	1,740,000
		43,325,050
o	Division 1 Costs @ 11% of Total[a]	5,354,950
		48,680,000
o	15% Contingency	7,302,000
ESTIMATED CONSTRUCTION COST		**$55,982,000**
	Engineering Design	3,900,000
	Services During Construction	3,900,000
	Administrative and Legal	2,800,000
TOTAL PROJECT COST		**$66,600,000**

[a]Division 1 costs include allowances for general conditions, mobilization, permits, bond, insurance, and winter protection costs.

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Table 8-15
ANNUAL OPERATION AND MAINTENANCE COSTS
FOR ALTERNATIVE 5

Description	Annual Cost
Labor and Materials	$ 95,000
Chemicals and Power	120,000
Sampling and Testing	22,000
Equipment Replacement Reserve	37,000
Site Review	10,000
TOTAL	$284,000

ALTERNATIVE 6: SIGNIFICANT PROTECTION OF HEALTH, WELFARE, AND ENVIRONMENT

Alternative 6 is the only one of the action alternatives that does not address each of the identified ARARs violations and human health concerns. It is also one of two action alternatives that do not fully attain ARARs. The components of Alternative 6 are all components of one or more of the first five alternatives. The major differences are that 1) the alternative does not address the transport of contaminated tailings down the bypass at flows greater than the capacity of the treatment system, and 2) the action proposed for isolating the tailings deposits and contaminated soils around the site that are above the assumed action levels would be flooding wherever possible. Pond 1 would be capped and the material along the bypass would be excavated and disposed of in Pond 1 prior to capping. Table 8-2 summarizes Alternative 6.

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The other components of Alternative 6 are utilized in one or more of the first five alternatives. They are analyzed against the five primary balancing factors with the alternative in which they first appear. These components include:

- Protecting the pond system against fractions of a PMF and a full MCE (Alternative 3)

- Excavation with onsite disposal of contaminated soils and tailings from the bypass (Alternative 3)

- A partial upgrade of the pond treatment system (Alternative 5)

- Development of an onsite wetland for groundwater treatment (Alternative 5)

Retaining Pond 2 in the treatment system while flooding the exposed sediments in the pond could require some modification of the flooding action as proposed under Media-Specific Action 8. The changes would be in design only, however, and would not affect the operation and/or effectiveness of the flooding action.

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Overall Protection of Human Health and the Environment

Alternative 6 addresses the majority of the risks to human health and the environment identified in the PHEA by using measures designed to control or eliminate those risks. Pond stability is addressed by protecting the ponds against both the MCE and a fraction of the PMF. The least protected of the ponds, Pond 1, would be protected against the flow of a 0.2 PMF, equal to approximately six times the flow of a 100-year flood. Pond 2 would be protected against a 0.3 PMF.

Pond 3 would be protected against a 0.5 PMF. Only under extreme flooding conditions would the stability of the pond berms be in question.

Alternative 6 would improve surface water quality for flows up to 210 cfs by removing tailings from along the bypass and modifying the pond treatment system. However, during flows greater than 210 cfs, water quality would be affected by the discharge of untreated water containing dissolved and suspended metals down the bypass. Additionally, in the long term, deposition of the suspended material may lead to recontamination of the bypass.

Contaminated groundwater moving from the site would be collected below Pond 1 and treated in an onsite wetland treatment system. This would reduce the discharge of further metals loading into the Clark Fork River and would result in compliance with Montana groundwater standards. Adoption of institutional controls prohibiting groundwater use could prevent human consumption of remaining contaminated water. Alternative 6 does not include groundwater collection from within Pond 1, which may hinder attempts to dewater and cap Pond 1, but should not affect the migration of contaminated groundwater from the site.

Flooding the tailings deposits and contaminated soils would minimize the threat of direct contact and hinder their airborne mobility. The permanence of flooding would be dependent on maintaining the water layers on the soil and tailings. If not maintained, the material would again become dried out and exposed. Flooding would not provide long-term protection against the mobility of metal contaminants in the surface water or groundwater or reduce the toxicity or volume of these materials.

All of the components of Alternative 6 are technically feasible. They would also, with appropriate design, construction, operation, and maintenance, reliably reduce the risks for which they are proposed. Increased risks to the surrounding environment and community during construction would be minimal if appropriate implementation measures are enacted.

Compliance with ARARs

Under the conditions defined below, Alternative 6 should result in compliance with some of the state and federal ARARs identified for the WSPOU. However, as described below, certain significant ARARs would not be met.

The actions proposed meet the Montana ARARs for protecting the pond system against flooding and earthquakes. Modest improvements to the pond treatment system should result in effluent compliance with surface water quality standards only at flows up to 210 cfs. Water quality standards at the site would be expected to result in regular water quality violations at flows over 210 cfs. Treating contaminated groundwater in an onsite wetland should result in compliance with Montana groundwater quality criteria. However, wetland treatment may be as consistently reliable as the pond treatment system proposed in Alternatives 1, 2 and 3. Excavating and moving tailings deposits and contaminated soils from the Mill-Willow bypass to Pond 1 prior to capping would comply with state and federal siting criteria for solid and hazardous waste disposal and would satisfy pertinent RCRA requirements for closure of hazardous waste management facilities. A complete summary of alternative action compliance with the state and federal ARARs addressed in this chapter is presented in Table 8-4.

The levels of remediation proposed in Alternative 6 could result in adverse effects on wetlands, endangered species, and historical resources due to migration and/or redeposition of contaminated tailings and soils. To mitigate these potential impacts, additional consultation with state and federal resource agencies will be required if this cleanup alternative is selected.

Long-Term Effectiveness

The long-term effectiveness of Alternative 6 is most affected by the fact that not all of the identified risks at the site are addressed by the alternative. No actions are taken to reduce the transport of tailings from upstream sources through the pond system at flows exceeding 210 cfs. Additionally, contaminated soils and tailings would be controlled using flooding to isolate the material.

The lack of a media-specific action to address the transport of upstream tailings would affect the risk level at the site and the long-term effectiveness of the alternative during above average surface water flows. Tailings suspended in the surface water could deposit and resuspend along the remaining reach of Silver Bow Creek, in the bypass, and in the Clark Fork River.

Through the deposition of suspended tailings and contaminated soils, areas of the site previously cleaned-up as part of this alternative (i.e., the bypass) could be recontaminated. Long-term monitoring and management of the area would be necessary in Alternative 6 to assess recontamination and its effects. Frequent cleanup and/or remediation along the bypass may be required to avoid future fishkills.

Flooding the contaminated soils and tailings above and below the pond system would address the primary risk associated with the tailings (health impacts resulting from inhalation, ingestion, or dermal contact) by isolating the material beneath a water surface. This would minimize direct contact and airborne dispersion. However, the water surface could encourage the dissolution of metal salts in the surface water, thereby increasing the amount of contaminated water on the site requiring treatment prior to discharge. The water from the flooded areas would need to be directed into the treatment pond following its release. Flooding would also increase the contaminant loading to the groundwater through leaching. Migration of the contaminated groundwater from beneath the flooding areas would occur in the direction of groundwater flow. The berms constructed to create the wetland below Pond 1 would be susceptible to damage by floods in that area.

In Alternative 6, the maintenance and monitoring requirements for the flooded areas would be minimal. The two primary requirements would be to maintain a minimal level of water over the whole area to prevent a potentially harmful buildup of metal salts in the water, and to maintain the berms.

Reduction of Toxicity, Mobility, Volume, Persistence, and Propensity to Bioaccumulate

In Alternative 6, flows in excess of 210 cfs would bypass the pond system by way of the Mill-Willow Bypass and flow into the Clark Fork River without treatment for either dissolved or suspended solids. Tailings could be deposited and

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resuspended through the entire reach of the bypass during each flow event routed around the ponds.

Flooding the contaminated soils and tailings in the areas above and below the treatment ponds would reduce the threat of inhalation and direct contact, but would not affect the toxicity, mobility, volume, or persistence of the materials, or their propensity to bioaccumulate. The potential mobility of the tailings deposits and contaminated soils within the operable unit would be higher than for any of the other five action alternatives. The flooding process could increase the amount of surface water to be treated for dissolved metals in Pond 3. Poor control of the water level could lead to re-exposure of the material.

Short-Term Effectiveness

Flooding the contaminated areas would not affect the community of Warm Springs. Construction contractors would need to wear protective equipment during preparation of the areas for flooding in order to prevent inhalation and dermal exposure to the tailings dust. The remaining risks to construction contractors should be limited to standard construction risks. The environmental impacts of the flooding process would be related to the alteration of wildlife habitat. With Alternative 6, approximately 600 acres of land that is currently divided between wetland and terrestrial habitat would become entirely wetlands.

Not addressing the transport of tailings through the operable unit would have no immediate, short-term impact on either the Warm Springs community or the remediation

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contractors. The long-term environmental impacts could be substantial, however. The primary environmental impact would be the continued deposition of tailings and contaminated soil along the bypass and in the Clark Fork Basin. Routine removal of newly deposited material would be necessary to keep the bypass free of tailings; otherwise, through continued deposition the bypass may be recontaminated to such an extent that fishkills would again be possible.

The remediation schedule for Alternative 6 is shown in Figure 8-6.

Implementability, Reliability, and Constructibility

The constructibility of the flooding option proposed for Alternative 6 is good. The reliability of flooding to adequately isolate the contaminated material is less certain than other alternatives. Flooding would minimize the threat of direct contact with the material, but it would increase its mobility through the surface water and groundwater.

Cost

Detailed cost estimates, including the assumptions used, are given in Appendix D. A summary of the capital costs associated with this alternative are shown in Table 8-16. Annual operation and maintenance costs are presented in Table 8-17. These costs are order-of-magnitude (+50 percent to -30 percent) estimates.

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TASK DESCRIPTION	1st YEAR												2nd YEAR												3rd YEAR												4th YEAR												5th YEAR											
	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
Design Investigations																																																										
Remedial Design																																																											
Permitting for Materials Quarries																																																											
Advertising, Bidding, and Award																																																											
Raise Berms Along Mill-Willow Bypass (Part. PMF)																																																											
Construct Embankment																																																											
Place Riprap																																																											
Improve Seismic Stability of Existing Berms																																																											
Foundation Construction																																																											
Construct Embankment																																																											
Scaled-Back Upgrade of Pond 3 Treatment System																																																											
Install Lime Treatment Facility																																																											
Improve Inlet Structure																																																											
Remediation of Contaminated Soils and Tailings																																																											
Excavate Along Mill-Willow Bypass																																																										
Drain Pond 1																																																											
Place Soil Cap in Pond 1																																																											
Wet Closure of Ponds 2 and 3																																																											
Seeding and Watering																																																												
Groundwater Collection and Wetlands Construction																																																											
Construct Groundwater Drain																																																											
Install Pump Station																																																											
Construct Wetland																																																											
Plant Vegetation																																																											

FIGURE 8-6

ESTIMATED PROJECT SCHEDULE
FOR ALTERNATIVE 6
WARM SPRINGS PONDS OUFS

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Table 8-16
WARM SPRINGS PONDS FEASIBILITY STUDY
COST EVALUATION OF ALTERNATIVES
ALTERNATIVE 6

Work Item Description		Cost Extensions Including Excess Labor Costs Due to Waste
MSA-1B:	Stabilize Pond Berms to Withstand Flood Flows Less Than the Probable Maximum Flood	$ 7,362,500
MSA-3:	Stabilize Berms to Withstand a Maximum Credible Earthquake	3,129,000
MSA-4:	Remove and Dispose of Contaminated Surface Soils Along Mill-Willow Bypass	917,000
MSA-5B:	Less Comprehensive Upgrade of Pond treatment system	1,484,750
MSA-8:	Flooding of Contaminated Soils and Tailings	16,844,250
MSA-11:	Groundwater Collection and Wetland Treatment Below Pond 1	4,048,300
Subtotal Alternative 6		**33,785,800**
o	Hazardous Waste Protection Costs	1,880,000
		35,665,800
o	Division 1 Costs @ 11% of Total[a]	4,408,200
		40,074,000
o	15% Contingency	6,011,000
ESTIMATED CONSTRUCTION COST		**$46,085,000**
	Engineering Desgin	3,200,000
	Services During Construction	3,200,000
	Administrative and Legal	2,300,000
TOTAL PROJECT COST		**$54,800,000**

[a]Division 1 costs include allowances for general conditions, mobilization, permits, bond, insurance, and winter protection costs.

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Table 8-17
ANNUAL OPERATION AND MAINTENANCE COSTS
FOR ALTERNATIVE 6

Description	Annual Cost
Labor and Materials	$ 84,000
Chemicals and Power	120,000
Sampling and Testing	22,000
Equipment Replacement Reserve	34,000
Site Review	10,000
TOTAL	$270,000

The present worth cost calculated for Alternative 6 is $55,100,000. Present worth was calculated using a 5 percent discount rate and a 30-year project life. Capital costs and long-term operations and maintenance (O&M) costs are included in the total present worth cost.

ALTERNATIVE 7: NO-ACTION ALTERNATIVE

Alternative 7 is the no-action alternative required by the National Contingency Plan. It is used as a baseline alternative against which to judge the other alternatives. As the name implies, this alternative does not include any remediation activities. The only activities assumed to continue are those being carried out by the owner (e.g., lime addition to the influent during winter months and general maintenance of the site).

The evaluation of this baseline alternative has been carried out using only the two primary evaluation criteria. The

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remaining criteria relate solely to the effectiveness and implementability of remediation technologies, and are not applicable to the no-action alternative.

Overall Protection of Human Health and the Environment

As identified above, no remediation activities would be undertaken as part of Alternative 7. Accordingly, there would be no reduction in risk or increase in protectiveness of human health and the environment. As a result of the continued occurrence of a number of processes on site (e.g., solids and sludge deposition in Ponds 2 and 3), the risks to human health and the environment would increase over time if left unmitigated.

Continued deposition of tailings and metal hydroxide sludges in Ponds 2 and 3 would add further mass behind the pond berms, increasing the potential impacts of berm failure.

Continued deposition in Pond 2 during average flow will also increase the threat of resuspension and dissolution of sediments during above average flows, resulting in a potential for increased exceedances of chronic and acute water quality standards at the compliance point for the operable unit.

Because the tailings deposits and contaminated surface soils along the bypass would remain unremediated, the formation of metal salts on the surface would continue during hot, dry periods. These salts could cause future fishkills during intense rain storms. Tailings eroded from the bypass or from upstream areas along Silver Bow Creek would continue to move into the Clark Fork River, adding to the contamination problem that already exists in and along that river.

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Failure to improve the pond inlet structure would lead to continued flows down the bypass of untreated water that could be treated, and continued deposition of tailings and contaminated soils both along the bypass and in the Clark Fork Basin. Failure to improve the pond treatment system would result in continued exceedances of water quality standards during high winds, high flow events, and winter conditions.

Assuming a lack of domestic, livestock, or irrigation use of the groundwater, a lack of groundwater collection and treatment from below the ponds would have a less immediate impact on human health and the environment than the other risk concerns; but, in the long term, the contaminated groundwater would continuously affect the water quality leaving the operable unit by acting as a separate source of metals.

Compliance with ARARs

Without remediation, the operable unit would not comply with many of the state and federal ARARs identified in Table 8-4. The pond system would continue to partially treat site surface waters, but regular exceedances of surface water quality standards would continue. Additionally, the existing treatment system would continue to be subject to flooding and/or earthquake damage; operable unit wastes stored in the ponds would not meet RCRA requirements for hazardous waste management facilities; the ponds would not meet Montana siting criteria for solid and hazardous waste storage; and contaminated groundwater at the operable unit would continue to exceed the maximum contaminant levels.

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Cost

No cost beyond current operations would be associated with the no-action alternative.

COMPARATIVE ANALYSIS OF ALTERNATIVES

This section presents a comparative analysis of the alternatives for each of the seven evaluation criteria. The purpose of this analysis is to identify the advantages and disadvantages of each alternative relative to the other alternatives.

The evaluation is presented using the seven evaluation criteria as headings. Under each heading the alternatives are discussed approximately in order of decreasing performance for that criterion.

A summary of the comparative analysis is presented in Table 8-18.

OVERALL PROTECTION OF HUMAN HEALTH AND ENVIRONMENT

Each of the first five alternatives addresses the eight human health and environmental concerns identified at the site to varying degrees of protectiveness. Alternative 6 leaves one of the concerns unaddressed--the transport of tailings down the bypass during flood flows in excess of 210 cfs. Alternative 7 is the no-action alternative; it would not alter the site, and it does not address any of the identified concerns.

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Table 8-18
SUMMARY OF COMPARATIVE ANALYSIS OF ALTERNATIVES

Overall Protectiveness	Compliance with ARARs	Long-Term Effectiveness	Reduction of Toxicity Mobility, and Volume	Short-Term Effectiveness	Implementability	Cost
All alternatives except 6 and 7 address all of the identified ARARs and human health concerns. Alternative 1 is the most protective in terms of the pond bottom sediments because it includes solidification as treatment. Alternative 2 protects the pond berms more than the remaining alternatives (full PMF vs. partial PMF). Alternatives 1 and 2 provide the greatest level of treatment for surface and groundwater. Alternatives 3 and 4 are not as protective for flows >600 cfs. Alternatives 5 and 6 only provide improved treatment for average flows. Alternative 1 is the most protective against tailings and contaminated soils by providing treatment. Alternative 2 removes the risk from the site but does not treat the material. Alternatives 3, 4, and 5 cap the material onsite, but Alternative 3 is the most protective because it consolidates the material. Alternative 6 is the least protective of the action alternatives, isolating the material through flooding but not permanently treating or immobilizing it.	See Table 8-4	Alternative 1 has the least residual risk through the treatment of tailings, sludges, and sediments. Threats associated with the presence of untreated tailings and sediments are minimized. Alternative 2 has the least residual risk of the alternatives that do not eliminate the current pond system because it protects the ponds against a full PMF. The remaining action, alternatives are equal in terms of controlling residual risk from the pond sediments. They all protect the ponds against a full MCE and a partial PMF They differ in the level of water treatment. The risk of untreated water flowing out of the operable unit increases with each alternative from 3 to 7. The onsite residual risks from contaminated soils and tailings are minimized in Alternatives 1 and 2. Alternative 3 reduces the residual risk by consolidating the material. Alternative 6 contains the greatest residual risk of the action alternatives because of a lack of treatment for surface water flows above 120 cfs and the potential mobility of tailings and soils onsite.	Only Alternative 1 includes treatment of pond bottoms as part of the remediation. The remaining action alternatives limit the mobility of the sediments. No alternative addresses the volume of pond bottom sediments. Alternatives 1 and 2 provide the greatest reduction in toxicity and volume of contaminated surface and groundwater. Alternatives 3, 4, 5, and 6 treat portions of the water flow to reduce its toxicity and the volume of contaminants, but with a decreasing effectiveness. Alternative 6 provides the least reduction in surface water toxicity, improving treatment only for average and less-than-average flowing out of the operable unit. Alternative 1 treats the tailings and contaminated soils at the site to reduce their mobility. The remaining alternatives contain actions to reduce the mobility of the material, but they do not include direct treatment. Alternative 2 removes the material from the site. Alternative 3 provides the best onsite containment using consolidation and a RCRA-equivalent cap.	None of the alternatives will significantly affect the Warm Springs community during implementation. It is likely that construction in the tailings and contaminated soil would result in some local airborne releases of the material, but this is not expected to affect the town of Warm Springs. Remediation contractors would have to be protected against dermal and inhalation threats while working in areas containing tailings and contaminated soils. These threats could be controlled using masks and protective clothing. This applies to all alternatives. All six alternatives will require planning to protect a pair of bald eagles living within the operable unit. Only Alternative 1 would substantially impact potential eagle habitat. Alternative 1 would take about 17 years to complete because of the large volume of pond sediments requiring solidification. The remainder of the alternatives would take 2 to 5 years to complete. The wetlands system included in Alternatives 5 and 6 may take up to 5 years of startup to meet the operational objectives.	The majority of components proposed for the alternatives are well developed and expected to be easily implemented at the Warm Springs Ponds site. This includes all pond berm stabilization, groundwater collection, surface and groundwater treatment, and soils excavation and/or containment. In situ solidification (Alternative 1) and wetlands treatment (Alternatives 5 and 6) are innovative technologies much less developed and predictable than the other components. In situ solidification has not been used for waste stabilization, and its effectiveness, completeness, and permanence are not known for certain. Pilot tests would be required prior to initiation to verify its feasibity. Wetlands treatment has been used with varying degrees of success in treating acid mine drainage. Based on those results, its use here is expected to be feasible, although the startup period needed to establish good operation may require up to 5 years. All seven alternatives need an MPDES permit for pond discharge.	Annual operation and maintenance costs are almost equal (about $300,000) for the six action alternatives. Present worth costs are as follows: Alt. 1--$1.19 billion Alt. 2--$241 million Alt. 3--$71 million Alt. 4--$77 million Alt. 5--$66 million Alt. 6--$55 million Alt. 7--the no-action alternative, has no costs beyond existing operations

Table 8-18 (continued)

Overall Protectiveness	Compliance with ARARs	Long-Term Effectiveness	Reduction of Toxicity Mobility, and Volume	Short-Term Effectiveness	Implementability	Cost
				Alternative 1 would have a greater impact on the surrounding environment than any of the other alternatives because of the replacement of the present pond system. This would eliminate a substantial amount of wetland habitat.		
		Operations, maintenance, and monitoring requirements would be fairly equal for all six action alternatives due to similar surface and groundwater treatment schemes for all alternatives. All six action alternatives would require continued surface and groundwater monitoring. The majority of O&M tasks are related to operation of the surface water treatment system, a component present in all alternatives. The wetlands treatment system (Alternative 5 and 6) will increase O&M during startup, but this will decrease once the system is operating to design specifications. Permanence is greatest for most comprehensive actions (e.g., solidification and flood impoundment).		The remaining alternatives would temporarily affect the wetland habitat, but it would, for the most part, be restored. All six action alternatives would convert rangeland habitat to a flood impoundment or settling pond. The settling pond (Alternatives 3-6) would alter less land (500 acres vs. 1,000 acres) than the flood impoundment. Alternatives 5 and 6 would increase the wetland habitat onsite through the construction of a wetlands treatment system.	The equipment and materials required for the majority of the components are readily available. The exceptions are the machinery needed for in situ stabilization (4 to 6 months to fabricate), and an adequate supply of riprap. The riprap may have to be quarried specifically for this job, which is a feasible alternative.	

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Overall, Alternative 1 is the most protective of the alternatives, because it alone contains measures to treat the pond bottom sediments, tailings deposits, and contaminated soils to permanently reduce their mobility. However, because in situ solidification is still a developing technology, its feasibility would have to be further explored during the predesign or design stage of the feasibility study. The remaining action alternatives (Alternatives 2-6) include measures to stabilize the pond berms to limit the mobility of the sediments and sludges by improving their existing containment. Alternatives 2 through 6 also include measures to contain the tailings and contaminated soils exposed at the surface throughout the operable unit either onsite (Alternatives 3-6) or offsite (Alternative 2).

Of the alternatives that do not eliminate the existing pond system (Alternatives 2-7), Alternative 2 offers the most protection against pond failure by protecting the pond berms against the maximum expectable forces--a probable maximum flood or a maximum credible earthquake. Alternatives 3 through 6 protect the pond berms against an MCE and fractions of a PMF as required by the Montana dam safety rules. The no-action alternative would be the least protective by leaving the berms in their present unstable state.

Containment measures for tailings deposits and contaminated soils are proposed for Alternatives 2 through 6. In general, the containment measures are not expected to be as protective or as permanent as the solidification action proposed for Alternative 1. This is because the tailings and soils would still exist in a form that could, in theory, be disturbed by severe weather or other forces, though the probability of dispersal of the contaminants would be very low for most of these alternatives. Alternative 2 includes off-

site disposal of the contaminated material. This would remove the direct threat from the site, but it would also introduce new risks and the liability associated with the offsite disposal of untreated material. Alternative 3 would consolidate the material onsite under a RCRA-equivalent cap. This could effectively contain the material without introducing the additional liabilities and risks of offsite disposal. Alternatives 4 and 5 would cap in place all of the material possible. Less protective caps would be used, and the lack of consolidation would increase maintenance costs and the potential for cap failure. Alternative 6, flooding, is the least protective of the action alternatives. Flooding these materials would limit direct contact but may increase mobility. Alternative 7 does not address the risks associated with the tailings deposits and contaminated soils.

The most significant differences in containment would be for the area below Pond 1. Because the area is not protected from floods by the pond berms, it will remain subject to flood forces for all the alternatives. Alternatives 1, 2, 3, and 5 would remove the contaminants from this area, either for solidification in the ponds (Alternative 1), offsite disposal (Alternative 2), or disposal in Pond 1 under a RCRA-equivalent cap (Alternatives 3 and 5). Alternative 4 would cap the contaminants in place. Alternative 6 would leave the contaminants in place, flooded under the wetland. Alternative 7 would leave the contaminants in their existing state.

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Neither the cap in Alternative 4 nor the wetland in Alternative 6 would provide significant protection of the contaminants from floods. The cap could be armored to protect it from small floods, but protection from large floods, such as 100-year or greater floods, would be difficult and very expensive; it would be much less difficult and expensive to excavate the materials and put them in one of the ponds where they would be protected from very large floods.

The surface water and groundwater actions included as parts of Alternatives 1 and 2 would provide the most effective and most comprehensive treatment for surface water and groundwater of the seven alternatives. Surface water treatment in an upgraded pond system would be provided for all flows up to the volume of a 100-year flood (13,000 acre-feet) or until the maximum flow of 4,000 cfs had been reached. With appropriate design and operation, water quality ambient and point source discharge standards should be met for nearly all flows up to the theoretical maximum 100-year flood flow of 4,000 cfs. Alternatives 3, 4, 5, and 6 include various levels of pond treatment, decreasing in the degree of effectiveness. Alternatives 3 and 4 would provide suspended solids treatment for flood flows between 600 and 4,000 cfs. Except for 2,000 acre-feet stored in the settling basin, flows above 600 cfs would not be treated for dissolved metals. Alternative 5 would upgrade the pond system, but it would only accept flows up to 210 cfs for dissolved metals treatment. Again, except for 2,000 acre-feet stored in the settling basin, flows between 210 and 4,000 cfs would receive treatment for suspended solids only. The lack of dissolved metals treatment for above-average flows would lead to increased violations of water quality standards for flows out of the operable unit. Because of the decreases in

levels or volume of treatment, water quality standards would be violated with greater frequency for each decrease in the upgrade of the treatment system. Alternatives 6 and 7 would likely experience regular violations during above average flows.

Trench drains for groundwater collection and treatment are included as part of all six action alternatives. Alternatives 1, 2, 3, and 4 include trench drains both in and below Pond 1. Alternatives 5 and 6 only call for a single drain below Pond 1. A single drain would effectively limit the offsite migration of contaminated groundwater but would not aid attempts to dewater Pond 1. Alternatives 1 through 4 would treat the groundwater in the pond system. Alternatives 5 and 6 include the addition of onsite wetlands for treatment. The wetlands system would decrease pumping requirements but could increase treatment operation and maintenance requirements and lead to further contamination of the soil and groundwater at the lower end of the site.

In general, permanence of the remedial actions is greatest for the more comprehensive alternatives. The solidification of pond bottom sediments is the only alternative that would permanently limit the mobility of the pond bottom sediments. Actions to stabilize the pond berms (Alternatives 2 through 6) would protect the sediments as long as they are maintained but would not permanently affect the sediments themselves.

Surface water treatment would continue for as long as the ponds are functional. The estimated life of Pond 3 is approximately 70 to 80 years. Pond 2 is only expected to last

about 15 years under average flows. The new treatment pond (Alternative 1) would be constructed with an estimated life of up to 100 years.

The permanence of efforts to cleanup the bypass would depend on efforts to keep the bypass free of future deposition. Alternatives 1 and 2 offer the greatest effectiveness, containing and treating all flows for suspended solids up to 4,000 cfs. For Alternatives 3, 4, and 5, flows up to 4,000 cfs would have up to 80 percent of the suspended solids load removed.

The permanence of soils and tailings remediation is greatest for Alternative 1 because all contaminated material would be solidified in the ponds. Alternatives 2 and 3 would contain the material in several consolidated units that would reduce maintenance requirements and aid permanence. The permanence of capping in-place or flooding (Alternatives 4 through 6) is much more dependent on the continued maintenance of the cap or cover.

COMPLIANCE WITH ARARs

Table 8-4 summarizes each alternative's compliance with federal and Montana ARARs.

LONG-TERM EFFECTIVENESS

The residual risk increases from Alternative 1 through the no-action alternative (Alternative 7), which involves the

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greatest residual risk. Alternative 1 would result in the least residual risk because the measures it includes to eliminate or contain the risks are more comprehensive than any of the other alternatives. This is primarily the case in regards to the pond bottom sediments and the tailings and contaminated soils. Alternative 1 is the only alternative to include treatment (solidification) of these materials. Although Alternative 2 would not reduce the residual risk to the same risk level as Alternative 1, it would protect the ponds from the threat of failure to a greater extent than the remaining alternatives, and it would remove the majority of the contaminated soils and tailings from the site. The residual risk in Alternative 2 results from the presence of the untreated pond bottom sediments onsite.

Alternatives 3 through 6, in turn, contain a slightly higher level of residual risk from the pond bottom sediments because the pond berms would be protected against only a fraction of a PMF, rather than a full PMF (Alternative 2). However, the probability of a catastrophic failure of the pond berms during a flood would still be small because the likelihood of even a 0.2 PMF is quite small. (No specific return intervals are associated with probable maximum floods, though their probability of occurrence is only once in several thousand years.) Alternative 7, which would not further stabilize the pond berms, would carry the greatest residual risk of flood damage to the ponds. The extent of environmental damage that would result from a pond failure would also increase over time with Alternative 7 because of the continued deposition of sediments within the pond.

Alternatives 1 and 2 would carry the least residual risk resulting from surface water and groundwater contamination.

Both alternatives include measures to treat basically all flows less than a 100-year flood passing through or from the system. Surface water flows up to a 100-year flood flow would be contained and treated for suspended solids and dissolved metals. Only flows greater than 100-year flood flow would pass through the system untreated.

The residual risks associated with contaminated surface water increase with each of the remaining alternatives. Alternatives 3 and 4, although treating most flows in an upgraded treatment system, include only suspended solids treatment for flows between 600 and 4,000 cfs that exceed 2,000 acre-feet. Alternatives 5 and 6 retain the current pond system with a few modifications and would only allow dissolved metals treatment in the ponds for flows up to 210 cfs because of the capacity limitations of Pond 2. For Alternative 5, flows between 210 and 4,000 cfs would be treated for suspended solids in the upstream settling basin. Up to 2,000 acre-feet of the flow would be retained and metered slowly into the ponds for dissolved metals treatment. The modification of the current pond system in Alternatives 5 and 6 also would not address the problem of potential short-circuiting in the ponds. Short-circuiting decreases the effectiveness of the ponds. Alternative 6, which does not include any treatment for flows greater than the current capacity of the treatment system (210 cfs), may eventually result in the recontamination of the bypass and the area below Pond 1.

Water quality standards for ambient and point source discharges should be met for all flows up to 4,000 cfs for Alternatives 1 and 2. Alternatives 3 and 4 may exceed these

water quality standards during flows above 600 cfs. Alternatives 5, 6, and 7 would experience more frequent violations and violations at lower flows than Alternatives 1 through 4.

Both of the groundwater treatment actions should be able to meet the appropriate treatment standards in the long term. However, pumping the collected groundwater to Pond 3 for treatment (Alternatives 1 through 4) would require less startup effort and less long-term operation and maintenance. The wetland system (Alternatives 5 and 6) would require periodic maintenance and/or replacement of vegetation, and more intensive care during winter months than the pumping option. The addition of the wetlands would also result in the eventual recontamination of soils, sediments, and groundwater in the treatment area, which may require future remediation during system closure.

The operation and maintenance requirements for all of the action alternatives would be fairly constant, because most of the requirements would be related to the water treatment systems. Alternatives 1 and 2 would require somewhat greater operation and maintenance than Alternatives 3, 4, 5, and 6 with respect to the requirements of the upstream flood impoundment. Alternatives 3, 4, and 5 would have less substantial operation and maintenance requirements associated with the upstream settling basin. Alternative 6 would require the periodic removal of tailings from the bypass. Alternatives 5 and 6 include a wetlands treatment system that would require some operation and maintenance. Alternatives 3 through 5 include onsite capping of contaminated material. Maintenance of the cap(s) will also increase the operation and maintenance requirements. Alternative 3,

which would consolidate the contaminated material under a single RCRA-equivalent cap, would have less maintenance requirements than the alternatives that would cap the material in place. Flooding the contaminants (Alternative 6) would potentially have the greatest maintenance costs while offering the least protection.

Monitoring requirements would basically be the same for all alternatives, limited to ensuring conformance with surface and groundwater standards. No monitoring above the current MPDES monitoring requirements would be added with Alternative 7, no-action.

REDUCTION OF TOXICITY, MOBILITY, AND VOLUME

Alternative 1 is the only alternative to use treatment in the remediation of pond bottom sediments and contaminated soils and tailings. This treatment would reduce the mobility of these materials by solidifying the sediments in place. It would also decrease the potential for leaching metals from the sediment. A drawback to the in situ solidification process is that it would substantially increase the total volume of the pond bottom material. Approximately 2 cubic yards of solidification agents would have to be added to every 1 yard of sediments treated in the wet portions of the ponds, thus tripling the volume of the sediments in these areas.

The remaining action alternatives would contain but would not treat the pond bottom sediments. The containment

actions would reduce the sediments' mobility to a lesser extent than Alternative 1 because they stabilize the containment structures but not the material itself. The containment actions would not affect the toxicity or volume of the material. Alternative 2 includes the most stringent of the containment actions, stabilizing the existing pond berms against the largest expectable forces, a PMF and an MCE. The remaining action alternatives would limit the mobility of the pond bottom material during events up to a full MCE and a fraction of a PMF. The no-action alternative would not affect the toxicity, mobility, or volume of the pond bottom material.

Remediation options proposed for the tailings and contaminated soils also vary in their effectiveness in limiting the future mobility of the material. Through offsite disposal of a majority of these materials, Alternative 2 removes the threat of remobilization at the site, although the material would continue to exist in an untreated state at a separate site. Alternative 3 offers the best onsite reduction in mobility through consolidation followed by containment under a RCRA-equivalent cap. Alternatives 4 and 5 would also reduce the mobility of the material, although not to the same extent as Alternative 3. Alternative 6 would not greatly reduce the mobility of the contaminated tailings and soils, although it would reduce the threat of direct contact.

All of the action alternatives include treatment to reduce the toxicity of the surface water to some degree. The alternatives differ in the amount and level of treatment. Alternatives 1 and 2 include treatment to reduce the toxicity of

contaminated water for all flow conditions up to a 100-year flood. Flows above the 100-year flood flow would bypass the system untreated.

The remaining alternatives reduce the toxicity of the surface water to a lesser extent. For Alternatives 3 and 4, only flows below 600 cfs and 2,000 acre-feet of flows above 600 cfs would be treated in the pond system for suspended solids and dissolved metals. Flows between 600 and 4,000 cfs would be treated for suspended solids only in the upstream impoundment. Alternatives 5 and 6 retain the present pond system with a few modifications to improve treatment. Alternative 5 includes a settling basin to contain up to 2,000 acre-feet and treat flows between 210 and 4,000 cfs for suspended solids. Flows above 210 cfs would not be treated for dissolved metals. Alternative 6 does not include any treatment for flows greater than the capacity of the current pond treatment system.

SHORT-TERM EFFECTIVENESS

Most of the components of the action alternatives would take 2 to 3 years to complete. The components are similar for the most part, varying primarily in size or layout. The solidification of the pond bottom sediments is an exception to this. Alternative 1 would require approximately 17 years to complete because of the large volume of soils and sediments to be solidified. Although the stability of the sediments would increase during the solidification process, it would still take a substantially longer time to reach complete protection from Alternative 1 than from any of the other alternatives.

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The wetlands treatment system included as part of Alternatives 5 and 6 may need up to 5 years startup time to reach the design objectives of the system. This time is needed to establish plant species in the system in order to realize effective treatment. None of the other treatment components included with the alternatives would require an extended startup period, though optimizing operation of a modified or new pond treatment system may require a full year or more of operational experience.

None of the action alternatives are expected to substantially affect the community of Warm Springs during remediation. Local releases of metal-contaminated tailings or dust would likely occur during construction work carried out in contaminated areas, but such releases would be minimized by dust control techniques and would not be expected to affect the community. There is also the potential for short-term violations of the water quality standards at the compliance point as a result of remediation work in or adjacent to the bypass and stream beds. Those violations would differ somewhat between alternatives and could be minimized through use of sedimentation barriers and sedimentation ponds.

Construction contractors would need protection against dermal and respiratory exposure to the tailings while working in contaminated areas. Dermal threats could be controlled using long-sleeve protective clothing, and inhalation threats could be controlled using appropriate dust or face masks. Health risks to operation and maintenance workers would be substantially less than for such workers under the existing conditions (see the PHEA, Appendix A). These risks would be similar for all alternatives.

Planning for all remediation activities would have to consider potential impacts to a pair of bald eagles, which are protected under the Endangered Species Act, that have previously nested within the operable unit. The eagles are not currently nesting within the operable unit but they continue to use the ponds as a food source during the summer months. Only Alternative 1 would substantially affect this food source. If the eagles return to nesting in the area surrounding the ponds, steps would be required to minimize any impact resulting from construction. This would be done during project planning in the design and construction phase of remediation. With attention to the necessary controls, adverse impacts to the eagles can likely be avoided. This would be true for all six of the action alternatives.

Environmental impacts to the operable unit would be greatest for Alternative 1 because of the in situ solidification process proposed for the existing ponds. Solidification of the existing ponds would alter several hundred acres of land that is currently wetland wildlife habitat. Prior to solidification, the ponds would be drained; about 17 years later, following solidification and covering with soil and vegetation, they would be left as dry, vegetated terrestrial habitat. Some of the lost open-water habitat would be replaced by the new treatment pond, which would be constructed upstream of the present ponds. The new flood impoundment pond, although not typically containing water, would permanently remove approximately 1,000 acres of rangeland from use, bringing the total acreage affected by this alternative to approximately 2,250 acres.

The remainder of the alternatives would not significantly affect the environment in and around the pond system on a long-term basis, except for the loss of wetlands in Pond 1 and the effects of the upstream impoundments. The flood impoundment, as discussed above, would affect approximately 1,000 acres. The smaller settling basin (Alternatives 3 through 5) would affect approximately 500 acres. Alternatives 2 through 6 would affect the local environment during implementation as a result of construction activities. These alternatives would affect the surrounding wildlife habitat with increased noise and dust levels. Some habitat would also be temporarily destroyed as a result of necessary earthwork. For Alternatives 3 through 6, these impacts would likely be short-lived and the areas returned to their preconstruction condition fairly quickly.

IMPLEMENTABILITY, RELIABILITY, AND CONSTRUCTIBILITY

For the most part, there is not a great deal of difference in the implementability of the six action alternatives. Most of the components proposed as part of the alternatives are well-developed technologies, used to some extent in either the hazardous waste, water, or standard civil engineering disciplines. The technical feasibility of these components appears to be good. The exceptions are the two innovative components included as part of a number of the alternatives: in situ solidification, and wetlands treatment for metals removal.

The technical feasibility of in situ pond bottom solidification (Alternative 1) is not known for certain at this time. It has been used with success to solidify marshlands for

foundation stabilization in Japan, but it has not been used extensively on hazardous waste sites. Consequently, it has a greater risk of implementation difficulties and failure than any of the other media-specific actions proposed for the pond bottom sediments. If it fails to adequately solidify the pond bottoms, for whatever reason, additional stabilization of the pond berms (as in Alternatives 2 through 6) would be necessary.

Wetlands treatment (Alternatives 5 and 6) has been used with some success for removing metals loadings from acid mine drainage, and its technical feasibility is somewhat more defined than in situ solidification. However, because effective treatment relies on the development of a resilient living ecosystem in the wetland, the implementation of an effective wetland could prove difficult and/or time consuming. The effectiveness of the wetlands system also depends to some extent on the weather. A large winter buildup of ice could result in severe short-circuiting in the wetland, decreasing the observed removal effectiveness. The technical feasibility of the other groundwater treatment component, which relies on treatment in the pond system (Alternatives 1-4), is greater.

The technical feasibility of the remainder of the components would be about equal. Protecting the pond berms against a fraction of a PMF (Alternatives 3-6) would be more feasible than protecting the berms from a full PMF (Alternative 2) simply because of the magnitude of the project. The same holds true for the upstream settling basin (Alternatives 3, 4 and 5) versus the upstream flood impoundment

(Alternatives 1 and 2). Because the settling basin would be smaller and would require fewer materials, its overall feasibility would be greater.

From an administrative feasibility standpoint, all of the alternatives are about equal. All seven alternatives (no-action alternative included) would require an MPDES permit to discharge water from the treatment system into the Clark Fork River. The discharge standards are more likely to be met for Alternatives 1 through 4 because they include a more comprehensive upgrading of the treatment system. They are not likely to be met with sufficient regularity under Alternatives 5 through 7.

Alternatives 1 through 5 would require the acquisition of 500 to 1,000 acres of rangeland for construction of the settling basin or the upstream flood impoundment. Because less land is needed for the smaller settling basin, it might be easier to implement.

The offsite disposal option, proposed for the majority of the tailings deposits and contaminated soils as part of Alternative 2, would be more difficult to implement than the remainder of the contaminated soils options. The interstate transport of up to 1.5 million cubic yards of untreated waste would be administratively undesirable from both a transportation and disposal point of view. The onsite disposal options (Alternatives 1 and 3-6) would likely be easier to implement.

An apparent lack of locally available riprap would favor the alternatives that require smaller amounts of that material (e.g., Alternatives 3-6 over Alternatives 1 and 2). This would be significant especially if the material would need to be quarried specifically for implementation. Other materials and equipment would be readily available for construction. The in situ solidification units for Alternative 1 would require up to 9 months for fabrication, but this could be incorporated into the scheduled implementation without causing unforeseen delay.

COST

The cost comparisons are straightforward. Comparing present worth costs, Alternative 1 is most expensive and Alternative 6 is the least expensive of the action alternatives. The long implementation schedule more strongly affects the present worth cost for Alternative 1 than do the implementation schedules of the other alternatives, which are shorter. The costs of the action alternatives are listed in Table 8-19, both with and without present worth considerations. The present worth analysis is detailed in Appendix D, Table D-7.

Sensitivity Analysis

A sensitivity analysis has been completed to evaluate the effects on project costs caused by variations in the assumptions associated with design, implementation, and operation. These assumptions depend on the accuracy of the data developed during the remedial investigation and this feasibility study. The effects on the cost of a specific action can be

Table 8-19
COST ESTIMATES FOR THE ACTION ALTERNATIVES

Cost Components	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6
Estimated Construction Cost	$1,665,000,000	$250,000,000	$60,100,000	$65,500,000	$56,000,000	$46,100,000
Engineering Design	4,000,000	4,000,000	4,200,000	4,600,000	3,900,000	3,200,000
Services During Construction	7,000,000	4,000,000	4,200,000	4,600,000	3,900,000	3,200,000
Administrative and Legal	3,000,000	3,000,000	3,000,000	3,300,000	2,800,000	2,300,000
Total Project Cost	1,679,000,000	261,000,000	71,500,000	78,000,000	66,600,000	54,800,000
Operation and Maintenance (Yearly Costs)	283,000	301,000	300,000	293,000	284,000	270,000
Total Present Worth Cost	$1,191,500,000	$241,500,000	$71,100,000	$77,000,000	$66,300,000	$55,100,000

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observed by varying the assumptions and noting the effects on the estimated costs.

The sensitivity analysis serves several functions:

- It outlines the areas of greatest uncertainty in the assumptions so that additional data can be gathered if more accurate cost estimates are required.

- It defines the "boundary conditions" of the cost estimates. In other words, it establishes reasonable maximum and minimum cost for the most uncertain cost elements.

- It identifies those areas requiring the greatest effort during the design phase to optimize the project costs.

The alternatives are discussed below in terms of the most cost sensitive assumptions associated with each. Tables were prepared evaluating the cost sensitivity of selected items of the construction cost estimates with the greatest uncertainties. These tables are presented in Appendix D as Tables D-8 through D-13. Not all of the uncertainties yielded major differences in overall project costs. Only those uncertainties that yielded large potential variations in the total project costs are discussed below.

Alternative 1

The factors that are most cost sensitive in Alternative 1 include:

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- The stabilization/solidification of the pond sediments
- The duration of the remediation
- The excavation, transportation, and disposal of the tailings and contaminated soils

Stabilize/Solidify Sediments. The extensive volume of existing pond sediments (19 million cubic yards) means that any variation in the unit price to treat them will yield a large variation in the overall project costs. Since stabilization/solidification is an untried technology in this application, the potential for significant variation in the unit price is large. In fact, one of the equipment vendors estimated that the construction costs could vary from $40 to $120 per cubic yard of material stabilized. The impacts of this variation (and the other potential construction cost variations) could cause the overall project cost to fluctuate by as much as 100 percent from the estimate. This is summarized in Table D-8.

Duration of Remediation. For the purposes of this feasibility study, it was assumed that four stabilization/solidification machines would be employed, and that they would take approximately 14 years to complete the remediation (see Chapter 7). If the number of machines was increased, this would shorten the schedule and impact the present worth analysis accordingly for this alternative. If 12 machines were utilized, the process would take approximately 5 years to complete. This could have a substantial effect on the total present worth of the project. See Table D-8.

Excavation, Transportation, and Disposal of Tailings. Under Alternative 1, all tailings and soils along the Mill-Willow Bypass and below Pond 1 would be excavated and transported to the nearest pond prior to stabilization/solidification. The estimates of the quantity of material above the action level are based on limited data. Thus, the quantity variations could be substantial, and could significantly affect the construction cost estimate for this action. The estimated potential variation in quantities and the impacts on construction costs are shown in Table D-8. The minimum quantity (30,000 cubic yards) assumes that one-half of the tailings would be above the action level. The maximum quantity (78,000 cubic yards) assumes that all the tailings would be above the action level.

Alternative 2

The primary factors which may cause substantial variation in the cost for Alternative 2 include:

- Quantities and unit costs associated with hauling contaminated soils to a RCRA facility
- Unit costs for riprap
- Quantities associated with foundation conditions in the existing ponds
- Magnitude of the maximum credible earthquake

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RCRA Facility Disposal. Alternative 2 assumes that all contaminated soils and unvegetated tailings above the action level would be excavated and transported to the nearest RCRA-permitted disposal facility. There are two significant factors associated with this assumption which could affect overall costs--unit costs and total quantities of material.

The unit costs could vary depending on the type of transportation (truck/trailer or train), routing, special requirements enroute, and disposal costs. The minimum unit cost ($180 per cubic yard) assumes transportation by train, no extraordinary enroute requirements, and discounted disposal costs due to the quantities and low toxicity of the materials. The maximum unit costs ($300 per cubic yard) assumes truck/trailer transport, special permitting and/or inspection requirements enroute, and elevated disposal costs caused by the quantities involved (e.g., requiring opening and permitting a new disposal area).

The quantities of tailings and soils excavated could vary depending upon the amount of material above the action level. Since the unit costs of transportation and disposal are so high, it was assumed that extensive testing and special care would be exercised in excavating only those materials above the action level. Thus, the minimum quantity was assumed to be approximately one-third of the contaminated soils. The maximum quantity was assumed to include all of the contaminated soils.

The impacts of the variations of these unit costs and quantities on the overall cost of this action are shown in Table D-9.

Riprap. The cost estimates shown in Appendix D assumed that the riprap would come from a limestone quarry approximately 5 miles west of Anaconda. If material from this quarry was not available in sufficient quantities or was otherwise unacceptable, another source would have to be located. The unit costs for riprap were assumed to vary from $20 per cubic yard (under good bidding conditions) to $30 per cubic yard (up to a 30-mile haul). The cost impacts of these assumptions are shown in Table D-9.

Foundation Conditions. Several quantities could vary significantly depending on foundation conditions in the existing ponds. These include flattening of the existing berm slopes to mitigate earthquake effects (Media-Specific Action 3 in Chapter 7) and construction of the berm and temporary cofferdam in Pond 3 (Media-Specific Action 5A in Chapter 7).

Flattening of the berm slopes requires that existing pond bottom sediments at the toe of the slopes be excavated until adequate foundation conditions are reached. Three feet of excavation were assumed for cost estimating purposes. For the sensitivity analysis, it was assumed that excavation depths could vary from 2 feet to 10 feet.

The construction of the berm across Pond 3 and the cofferdam required to construct the new outlet structure require special considerations. They will likely be constructed "in the wet" by pushing gravel and rock out from one of the berms. Because the gravel and rock must be placed on top of the existing pond sediments, the quantity of material required is uncertain. The reason is that the rock and

gravel will tend to displace the sediments and sufficient material must be placed until stability is achieved. For the purposes of the sensitivity analysis, it was assumed that as much as twice the estimated quantity of material may be required before stability is achieved.

The cost impacts of the foundation condition assumptions are shown in Table D-9.

Maximum Credible Earthquake. Greater berm stability to withstand the shaking forces of earthquakes would be achieved by flattening the slopes of the berms. The current slopes are as steep as 1.4:1 (horizontal to vertical), and would be flattened to 2.5:1 under the assumption used in this study. The 2.5:1 slope was selected based on available information on the berm construction materials and on the estimated maximum credible earthquake. As noted in Chapter 4, a site-specific earthquake study will be required during the design investigation. If that study results in a substantially different estimate of the maximum credible earthquake, the final slopes for the berms may be either greater or less than 2.5:1. For purposes of the sensitivity analysis, it was assumed that the final slopes may need to be as flat as 3.5:1. The cost difference due to this variation is shown in Tables D-9 through 13.

Alternative 3

The major cost variables for Alternative 3 include:

- Quantities of contaminated soils and tailings

- Unit costs for riprap
- Quantities for foundations for the berm slope flattening
- Quantities in the berm and cofferdam in Pond 3
- Magnitude of the maximum credible earthquake
- Quantities for the wet closure of Pond 2

The uncertainties regarding quantities of contaminated soils and tailings are discussed under Alternative 1 above. The uncertainties regarding riprap, foundations for the berm slope flattening, the berm and cofferdam in Pond 3, and the magnitude of the maximum credible earthquake are discussed under Alternative 2 above. The magnitude of the uncertainties and their cost ramifications for Alternative 3 are shown in Table D-10. The variability in quantities for the wet closure of Pond 2 is discussed below.

Pond 2 Wet Closure. The southern portion of Pond 2 would be flooded through construction of an additional berm across Pond 2 (see media-specific action 8 in Chapter 7). This berm would be constructed across pond bottom soils with unknown foundation conditions, causing uncertainties in estimating berm quantities. For this sensitivity analysis, it was assumed that as much as 7 feet of material would have to be removed and replaced to reach adequate foundation materials beneath the berm. The cost difference due to this variation in quantities is shown in Table D-10.

Alternative 4

The major cost variables for Alternative 4 include:

- Quantities of contaminated soils and tailings
- Unit costs for riprap
- Quantities of foundation materials required for berm slope flattening
- Quantities in the berm and cofferdam in Pond 3
- Magnitude of the maximum credible earthquake

The reasoning behind the cost variations of each of these items has been discussed above. The magnitude of the variations for Alternative 4 is shown in Table D-11.

Alternative 5

The major cost variables for Alternative 5 include:

- Quantities of contaminated soils and tailings
- Unit costs for riprap
- Quantities of foundation materials required for berm slope flattening
- Magnitude of the maximum credible earthquake

- Foundation quantities for the Pond 2 wet closure berm

Each of these cost variations has been discussed previously. The dollar amounts resulting from the cost variations are shown in Table D-12.

Alternative 6

The major cost variables for Alternative 6 include:

- Quantities of contaminated soils and tailings
- Unitecosts for riprap
- Quantities of foundation materials required for berm slope flattening
- Magnitude of the maximum credible earthquake
- Quantities of foundation materials required beneath the berms to wet close Ponds 2 and 3

Each of these variables has been discussed previously. The costs are shown in Table D-13.

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